

SECTION 1000. MATERIALS

GENERAL

SECTION 1001. PORTLAND CEMENT OR BLENDED HYDRAULIC CEMENT

**1001.01 Specifications.** Portland cement, portland-pozzolan cement and portland blast-furnace slag cement shall be according to ASTM specifications and meet the standard physical and chemical requirements. The Engineer may specify optional physical and chemical requirements. ASTM sampling and test procedures will be used to verify the requirements in ASTM specifications. Specific references to the types of cement are as follows:

<u>Specifications for:</u>	<u>Type</u>	<u>ASTM</u>
Portland Cement <sup>1</sup>	I, II, III, IV, V, IA, IIA, IIIA	C 150
Portland-Pozzolan Cement <sup>2</sup>	IP, I(PM), IP(MS) IP-A, I(PM)-A, IP-A(MS)	C 595
Portland Blast-Furnace Slag Cement <sup>3</sup>	IS, I(SM), IS(MS), IS-A, I(SM)-A, IS-A(MS)	C 595

- 1/ Type I portland cement may be used at the option of the Contractor. Type IA, II, IIA, III, IIIA, IV, and V portland cement may be when specified or when approved in writing by the Engineer.
- 2/ Type IP portland-pozzolan cement or Type I(PM) pozzolan-modified portland cement may be used at the option of the Contractor provided the pozzolan constituent does not exceed 21 percent of the mass (weight) of the portland-pozzolan cement. Type IP- A, I(PM)-A, IP(MS), and IP-A(MS) portland-pozzolan cement may be used when specified or when approved in writing by the Engineer. Portland-pozzolan cements shall not be used after October 15 nor before April 1.
- 3/ Type IS portland blast-furnace slag cement or Type I(SM) slag-modified portland cement may be used at the option of the Contractor provided the slag constituent does not exceed 25 percent of the mass (weight) of the portland blast-furnace slag cement. Type IS-A, I(SM)-A, IS(MS), and IS-A(MS) portland blast-furnace slag cement may be used when specified or when approved in writing by the Engineer. Portland blast-furnace slag cements shall not be used after October15 nor before April 1.

For portland cement according to ASTM C 150, the total of all organic processing additions shall not exceed 1.0 percent by mass (weight) of the cement, and the total of all inorganic processing additions shall not exceed 4.0 percent by mass (weight) of the cement. Organic processing additions shall be limited to grinding aids that

improve the flowability of cement, reduce pack set, and improve grinding efficiency. Inorganic processing additions shall be limited to granulated blast-furnace slag according to the chemical requirements of AASHTO M 302, and Class C fly ash according to the chemical requirement of AASHTO M 295.

For portland-pozzolan cement and portland blast-furnace slag cement according to ASTM C 595, the total of all organic processing additions shall not exceed 1.0 percent by mass (weight) of the cement. Organic processing additions shall be limited to grinding aids as previously defined. Inorganic processing additions shall not be permitted.

The bill of lading shall state if granulated blast slag or Class C fly ash has been used as a processing addition. The bill of lading shall also have a statement that indicates the inorganic processing addition is not in excess of 4.0 percent by mass (weight) of the cement.

**1001.02 Mixture Designs.** Cement factors of mixes containing portland-pozzolan cement or portland blast-furnace slag cement may be adjusted by the Engineer to meet the mix design strength requirement of Article 1020.04.

**1001.03 Uniformity of Color.** Cement contained in single loads or in shipments of several loads to the same project shall be uniform in color. Visible differences in the color shall be cause for rejection.

**1001.04 Mixing Brands and Types.** Different brands or different types of cement from the same manufacturing plant, or the same brand or type from different plants shall not be mixed or used alternately in the same item of construction unless approved by the Engineer.

**1001.05 Storage.** Cement shall be suitably stored and protected against dampness. Cement which has partially set or contains hardened lumps will be rejected. Different brands or different types of cement from the same manufacturing plant, or the same brand or type from different plants shall be kept separate.

**1001.06 Sampling and Testing.** The Department may sample and test cement at the manufacturing plant or one of its terminals. Provisions of Article 106.04 shall apply, except an approved sampling location and the necessary personnel to assist the Department representative in obtaining samples shall be provided.

The Department may sample and test cement at the final destination. An approved sampling location and the necessary personnel to assist the Department representative in obtaining samples shall be provided by the Contractor, or the Concrete Producer with whom the Contractor has contracted materials.

The Engineer will permit the use of the cement provided the bill of lading indicates a manufacturing plant which is on the current list of qualified plants. If the cement is not from a qualified plant, the Engineer will permit the use of the cement provided the bill of lading states the manufacturer of the cement, and the cement was tested and approved by the Department according to the Bureau of Materials and Physical Research's Policy Memorandum, "Portland or Blended Cement Acceptance Procedure for Qualified and Non-Qualified Plants".

## SECTION 1002. WATER

**1002.01 Quality.** Water used with cement in concrete, mortar, and water used for curing concrete shall be clean, clear, free from sugar and shall not contain acid, alkali, salts or organic matter in excess of the following amounts when tested according to AASHTO T 26:

- (a) Acidity and Alkalinity
  - (1) Acidity--0.1 Normal NaOH 2 ml max.\*
  - (2) Alkalinity--0.1 Normal HCl 10 ml max.\*

\*To neutralize 200 ml sample.
- (b) Total Solids
  - (1) Organic .....0.02% max.
  - (2) Inorganic.....0.30% max.
  - (3) Sulphuric anhydride (SO<sub>3</sub>) .....0.04% max.
  - (4) Alkali chloride as sodium chloride (NaCl) .....0.10% max.

When test data on standard cement specimens made with cement, sand and water from the sample are compared with data obtained on specimens made with the same cement and sand and distilled water, there shall be no indication of unsoundness, marked change in time of set, or variation of more than ten percent in strength.

**1002.02 Approval of Source.** Water which has been approved by the Illinois Department of Public Health for drinking or ordinary household use may be accepted without being tested. All other sources must be approved by the Engineer.

The Contractor shall not use water from shallow, muddy or marshy surfaces. The intake of the pipe line shall be enclosed to exclude silt, mud, grass and other solid materials, and there shall be a minimum depth of 600 mm (2 ft) of water below the intake at all times.

## SECTION 1003. FINE AGGREGATES

**1003.01 Materials.** The aggregate materials shall conform to the following requirements:

- (a) Description. The natural and manufactured materials used as fine aggregate are defined as follows:

**Sand.** Sand shall be the fine granular material resulting from the natural disintegration of rock. Sand produced from deposits simultaneously with and by the same operations as gravel coarse aggregate may contain crushed particles in the quantity resulting normally from the crushing and screening of oversize particles.

**Silica Sand.** Silica sand shall be composed of not less than 99.5 percent silica (SiO<sub>2</sub>).

**Stone Sand.** Stone sand shall be produced by washing or processing by air separation the fine material resulting from crushing rock quarried from undisturbed, consolidated deposits or crushing gravel.

**Screenings.** Screenings shall be the fine material resulting from crushing rock quarried from undisturbed, consolidated deposits or from crushing gravel.

**Chats.** Chats shall be the tailings resulting from the separation of metals from rocks in which they occur.

**Wet Bottom Boiler Slag.** Wet bottom boiler slag shall be the hard, angular by-product of the combustion of coal in wet bottom boilers.

**Slag Sand.** Slag sand shall be the graded product resulting from the screening of air cooled blast furnace slag. Air cooled blast furnace slag shall be the nonmetallic product, consisting essentially of silicates and aluminosilicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace.

The acceptance and use of air-cooled blast furnace slag shall also be according to the current Bureau of Materials and Physical Research Policy Memoranda, "Crushed Slag Producer Certification and Self-Testing Program" and "Slag Producer Self-Testing Program".

**Granulated Slag Sand.** Granulated slag sand shall be the graded product resulting from the screening of granulated slag. Granulated slag shall be the nonmetallic product, consisting essentially of silicates and aluminosilicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace. Granulated slag sand is formed by introducing a large volume of water under high pressure into the molten slag.

**Steel Slag Sand.** Steel slag sand shall be the graded product resulting from the screening of crushed steel slag. Crushed steel slag shall be the nonmetallic product which is developed in a molten condition simultaneously with steel in an open hearth, basic oxygen or electric furnace.

**Crushed Concrete Sand.** Crushed concrete sand shall be the angular fragments resulting from crushing portland cement concrete by mechanical means. The acceptance and use of crushed concrete sand shall be according to the latest Bureau of Materials and Physical Research policy memorandum.

**Construction and Demolition Debris Sand.** Construction and demolition debris sand shall be the angular fragments resulting from mechanical crushing/screening of unpainted exterior brick, mortar, and/or concrete with small amounts of other materials. Construction and demolition debris sand shall meet all the requirements of the current Bureau of Materials and Physical Research policy memorandum.

- (b) Quality. The fine aggregate shall be from an approved source and shall meet the quality standards listed in the following table and will be accepted on the basis of these tests unless unfavorable conditions showing up in usage indicate the material is unsatisfactory. Except for the minus 75  $\mu\text{m}$  (No. 200) sieve material, all fine aggregate shall meet specified quality requirements before being proportioned for mix or combined to adjust gradation. The blended materials shall meet the minus 75  $\mu\text{m}$  (No. 200) sieve requirements.

At the time of its use, the fine aggregate shall be free from frozen material, material used to caulk rail cars, and all foreign materials which may have become mixed with it during transportation and handling.

FINE AGGREGATE QUALITY			
QUALITY TEST	CLASS		
	A	B	C
Na <sub>2</sub> SO <sub>4</sub> Soundness 5 Cycle, AASHTO T 104 <sup>1/</sup> / Max. % Loss	10	15	20
Minus 75 $\mu\text{m}$ (No. 200) Sieve Mat'l. AASHTO T 11 Max. % <sup>5/</sup>	3	6 <sup>2/</sup>	10 <sup>2/</sup>
Organic Impurities Check – AASHTO T 21	Yes <sup>3/</sup>	---	---
Deleterious Mat'ls. <sup>4/</sup> - Shale Max. %	3.0	3.0	
- Clay Lumps Max. %	1.0	3.0	
- Coal, Lignite & Shells Max. %	1.0	3.0	
- Conglomerate Max. %	3.0	3.0	
- Other Deleterious Max. %	3.0	3.0	
- Total Deleterious Max. %	3.0	5.0	

- 1/ As modified by the Department.
  - 2/ Does not apply to Gradations FA 20 or 21.
  - 3/ Applies only to Sand. Sand exceeding the colorimetric test standard of 11 (AASHTO T 21) will be checked for mortar making properties according to the Illinois Modified AASHTO T 71, and shall develop a compressive strength at the age of 14 days when using Type I or II Cement of not less than 95 percent of the comparable standard.
  - 4/ Applies only to sand.
  - 5/ Fine aggregate used for bituminous mixtures shall not contain more than three percent clay (2 micron or smaller) particles as determined by the Department.
- (c) Gradation. The fine aggregate shall be uniformly graded from coarse to fine, and when tested by means of laboratory sieves (square openings), the aggregate shall conform to the designated gradation.

The gradations prescribed may be manufactured by any suitable commercial process and by the use of any sizes or shapes of plant screen openings necessary to produce the sizes within the limits of the sieve analysis specified.

The gradation numbers and corresponding gradation limits are listed in the following table and represent the limits which will determine suitability for use from all approved sources of supply. The gradation of the material from any one source shall be reasonably uniform and shall not be subject to the extreme percentages of gradation represented by the tolerance limits of the various sieve sizes.

FINE AGGREGATE GRADATIONS SIEVE SIZE											
Grad No.	Percent Passing										
	9.5 mm	4.75 mm	2.36 <sup>4/</sup> mm	2.00 mm	1.18 mm	600 <sup>5/</sup> µm	425 µm	300 µm	180 µm	150 µm	75 <sup>1/</sup> µm
FA 1	100	97±3			65±20			16±13		5±5	
FA 2	100	97±3			65±20			20±10		5±5	
FA 3	100	97±3		80±15			50±20		25±15		3±3
FA 4	100				5±5						
FA 5	100	92±8								20±20	15±15
FA 6		92±8 <sup>2/</sup>								20±20	6±6
FA 7		100		97±3			75±15		35±10		3±3
FA 8			100				60±20			3±3	2±2
FA 9			100					30±15		5±5	
FA 10				100			90±10		60±30		7±7
FA 20	100	97±3	80±20		50±15			19±11		10±7	4±4
FA 21 <sup>3/</sup>	100	97±3	80±20		57±18			30±10		20±10	9±9

FINE AGGREGATE GRADATIONS SIEVE SIZE (ENGLISH UNITS)											
Grad No.	Percent Passing										
	3/8	No. 4	No. 8 <sup>4/</sup>	No. 10	No. 16	No. 30 <sup>5/</sup>	No. 40	No. 50	No. 80	No. 100	No. 200 <sup>1/</sup>
FA 1	100	97±3			65±20			16±13		5±5	
FA 2	100	97±3			65±20			20±10		5±5	
FA 3	100	97±3		80±15			50±20		25±15		3±3
FA 4	100				5±5						
FA 5	100	92±8								20±20	15±15
FA 6		92±8 <sup>2/</sup>								20±20	6±6
FA 7		100		97±3			75±15		35±10		3±3
FA 8			100				60±20			3±3	2±2
FA 9			100					30±15		5±5	
FA 10				100			90±10		60±30		7±7
FA 20	100	97±3	80±20		50±15			19±11		10±7	4±4
FA 21 <sup>3/</sup>	100	97±3	80±20		57±18			30±10		20±10	9±9

- 1/ Subject to maximum percent allowed in Fine Aggregate Quality Table.
- 2/ 100 percent shall pass the 25 mm (1 in.) sieve except that for bedding material 100 percent shall pass the 9.5 mm (3/8 in.) sieve. If 100 percent passes the 12.5 mm (1/2 in.) sieve, the 4.75 mm (No. 4) sieve may be 75 ± 25.
- 3/ For Class I, Type 2. When used, either singly or in combination with other sands, the amount of material passing the 75 µm (No. 200) sieve (washed basis) in the total sand fraction for mix design shall not exceed ten percent.
- 4/ For each gradation used in bituminous mixtures, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ±15 percent. The midpoint shall not be changed without Department approval.
- 5/ For each gradation used in bituminous mixtures, the aggregate producer shall set the midpoint percent passing, and the Department will apply a range of ±13 percent. The midpoint shall not be changed without Department approval.

(d) Incompatibility. Incompatibility of any of the gradations or combinations of gradations permitted resulting in unworkable mixtures, nonadherence to the final mix gradation limits, or any other indication of incompatibility shall be just cause for rejection of one or both of the sizes.

- (e) Storage of Fine Aggregate. Sites for storage of all fine aggregates shall be grubbed and cleaned prior to storing the material. Stockpiles shall be built in such a manner as to prevent segregation and to ensure reasonably uniform gradation throughout the stockpile. Stockpiles shall be separated to prevent intermingling at the base. If partitions are used, they shall be of sufficient heights to prevent intermingling. Fine aggregates for portland cement concrete and bituminous mixtures shall be handled in and out of the stockpiles in such a manner that will prevent contamination.

Unless otherwise directed by the Engineer, fine aggregate of various gradations and from different sources shall be stockpiled separately.

**1003.02 Fine Aggregate for Portland Cement Concrete and Mortar.** The aggregate shall conform to the requirements of Article 1003.01 and the following specific requirements:

- (a) Description. The fine aggregate shall consist of washed sand. Stone sand will be permitted for portland cement concrete provided it is blended with natural sand in the proportions satisfactory to the Engineer.
- (b) Quality. The fine aggregate materials in the gradations specified for portland cement concrete shall be Class A Quality. The fine aggregate for mortar for masonry shall be from natural aggregate pits approved for Class A Quality or shall meet the deleterious quantity limits for Class A Quality.
- (c) Gradation. The fine aggregate for portland cement concrete shall be Gradation FA 1. When permitted, Gradation FA 2 may be used in lieu of FA 1. Fine aggregate for mortar for masonry shall be Gradation FA 9.
- (d) Mixing Fine Aggregates. The mixing, alternate use, and/or substitution of fine aggregates from different sources for use in portland cement concrete will not be permitted without the approval of the Engineer. When mixing is permitted, the method of combining the fine aggregates shall be such as to produce a consistently uniform mixture, and the arrangements for mixing shall be satisfactory to the Engineer.

**1003.03 Fine Aggregate for Bituminous Mixtures.** The aggregate shall conform to the requirements of Article 1003.01 and the following specific requirements:

- (a) Description. Fine aggregate for bituminous mixtures shall consist of sand, stone sand, slag sand or chats. For Class I, all types, steel slag sand will also be allowed. Fine aggregate for top dressing of bituminous surfaces shall consist of sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand or steel slag sand.
- (b) Quality. The fine aggregate for bituminous mixtures Class I, all types shall be Class B Quality or better.

The fine aggregate for Class B mixtures, where the Class B mixture aggregate is composed of separate sizes, shall be Class C Quality or better. The fine aggregate used as blotter material on oiled earth surface where the



required curing period is not feasible shall be a hard durable material reasonably free of soft and unsound particles.

- (c) Gradation. The fine aggregate gradations shall be as follows:

For Class I, all types, the gradation shall be FA 1, FA 2 or FA 20. For Class I, Types 2 and 3, FA 21 may also be used. For Class I, Types 2 and 3, the FA 21 gradation shall consist of stone sand, slag sand or steel slag sand only, or a mechanical blend of stone sand, slag sand or steel slag sand and natural sand.

Gradation FA 1, FA 2 or FA 3 shall be used when required for prime coat aggregate application for Class I and Class B.

Gradation FA 7 shall be used when specified. Gradation FA 1, FA 2, FA 3 or FA 4 shall be used for blotter material on oiled earth surfaces where the required curing period is not feasible.

- (d) Source of Supply. All sources of supply shall be approved by the Engineer. The Contractor shall submit to the Engineer a statement giving the sources of fine aggregate. Only fine aggregates from these sources shall be used on the job unless approval in writing is obtained from the Engineer.

**1003.04 Fine Aggregate for Trench Backfill, Sand Backfill for Underdrains, Bedding, Porous Granular Backfill and French Drains.** The aggregate shall conform to the requirements of Article 1003.01 and the following specific requirements:

- (a) Description. The fine aggregate shall consist of sand, stone sand, stone screenings, chats, wet bottom boiler slag, slag sand or granulated slag sand. Crushed concrete sand and construction and demolition debris sand may be used in lieu of the above for trench backfill.
- (b) Quality. The fine aggregate shall be reasonably free from an excess of soft and unsound particles and other objectionable matter.
- (c) Gradation. The fine aggregate for trench backfill shall be Gradation FA 6. The fine aggregate for porous granular embankment and backfill and french drains, sand backfill for underdrains and bedding shall be Gradation FA 1 or FA 2, except the percent passing the 75  $\mu$ m (No. 200) sieve shall be  $2 \pm 2$ .

**1003.05 Fine Aggregate for Membrane Waterproofing.** The aggregate shall conform to the requirements of Article 1003.01 and the following specific requirements:

- (a) Description. The fine aggregate shall consist of sand, stone sand, wet bottom boiler slag, slag sand or chats.
- (b) Quality. The fine aggregate shall meet the Class B Quality Deleterious Count, and when subjected to five cycles of the Department's sodium sulfate soundness test (AASHTO T 104), the weighted average loss shall not be more than ten percent.

- (c) Gradation. The fine aggregate shall be Gradation FA 8.

## SECTION 1004. COARSE AGGREGATE

**1004.01 Materials.** The aggregate materials shall conform to the following requirements:

- (a) Description. The natural and manufactured materials used as coarse aggregate are defined as follows:

Gravel. Gravel shall be the coarse granular material resulting from the reduction of rock by the action of the elements and having subangular to rounded surfaces. It may be partially crushed.

Chert Gravel. Chert gravel shall be the coarse granular material occurring in alluvial deposits resulting from reworking by weathering and erosion of chert bearing geological formations and containing a minimum of 80 percent chert or similar siliceous material.

Crushed Gravel. Crushed gravel shall be the product resulting from crushing by mechanical means, and shall consist entirely of particles obtained by crushing gravel, all of which before crushing will be retained on a screen with openings equal to or larger than the maximum nominal size of the resulting crushed material. If approved by the Engineer, final product gradations may be obtained by screening or blending various sizes of crushed gravel material.

Pit or Bank Run Gravel. Pit or bank run gravel shall be a mixture of sand, gravel, silt and clay occurring naturally in a deposit, which is of such quality that it may be used with only minor processing.

Novaculite Gravel. Novaculite gravel shall be material occurring in natural deposits, composed of angular particles of siliceous origin and mixed with ferruginous clay.

Crushed Stone. Crushed stone shall be the angular fragments resulting from crushing by mechanical means the following types of rocks quarried from undisturbed, consolidated deposits: granite and similar phanocrystalline igneous rocks, limestone, dolomite, sandstone, or massive metamorphic quartzite, or similar rocks. Dolomite shall be a carbonate rock containing 11.0 percent or more magnesium oxide (MgO). Limestone shall be a carbonate rock containing less than 11.0 percent magnesium oxide (MgO).

Wet Bottom Boiler Slag. Wet bottom boiler slag shall be the hard, angular by-product of the combustion of coal in wet bottom boilers.

Crushed Slag. Crushed slag shall be the graded product resulting from the processing of air cooled blast furnace slag. Air cooled blast furnace slag shall be the nonmetallic product, consisting essentially of silicates and

alumino-silicates of lime and other bases, which is developed in a molten condition simultaneously with iron in a blast furnace. It shall be air cooled and shall have a compact weight (AASHTO T 19) of not less than 1100 kg/cu m (70 lb/cu ft).

The acceptance and use of air-cooled blast furnace slag shall be according to the current Bureau of Materials and Physical Research Policy Memoranda, "Crushed Slag Producer Certification and Self-Testing Program" and "Slag Producer Self-Testing Program".

Crushed Sandstone. Crushed sandstone shall be the angular fragments resulting from crushing, by mechanical means, a cemented sand composed predominantly of quartz grains.

Crushed Concrete. Crushed concrete shall be the angular fragments resulting from crushing portland cement concrete by mechanical means. The acceptance and use of crushed concrete shall be according to the latest Bureau of Materials and Physical Research policy memorandum.

Chats. Chats shall be the tailings resulting from the separation of metals from the rocks in which they occur.

Crushed Steel Slag. Crushed steel slag shall be the graded product resulting from the processing of steel slag. Steel slag shall be the nonmetallic product which is developed in a molten condition simultaneously with steel in an open hearth, basic oxygen or electric furnace.

Crushed Copper Slag. Crushed copper slag shall be the graded product resulting from the processing of copper slag. Copper slag shall be the non-metallic product developed in a molten condition simultaneously with copper in a smelter.

- (b) Quality. The coarse aggregate shall be from an approved source and shall meet the quality standards listed in the following table and will be accepted on the basis of these tests unless unfavorable conditions showing up in usage indicate the material is unsatisfactory. All coarse aggregate materials shall meet the specified quality requirements before being proportioned for mix or combined to adjust gradation.

COARSE AGGREGATE QUALITY				
QUALITY TEST	CLASS			
	A	B	C	D
Na <sub>2</sub> SO <sub>4</sub> Soundness <sup>2/</sup> 5 Cycle, AASHTO T 104 <sup>1/2/</sup> Max. % Loss	15	15	20	25 <sup>3/</sup>
Los Angeles Abrasion AASHTO T 96 Max. % Loss	40 <sup>4/</sup>	40 <sup>5/</sup>	40 <sup>6/</sup>	45
Minus 75 µm (No. 200) Sieve Mat'l. AASHTO T 11	1.0 <sup>8/</sup>		2.5 <sup>9/</sup>	
Max. % Deleterious Mat'ls. <sup>7/</sup>				
- Shale Max. %	1.0	2.0	4.0 <sup>10/</sup>	
- Clay Lumps Max. %	0.25	0.5	0.5 <sup>10/</sup>	
- Coal & Lignite Max. %	0.25			
- Soft & Unsound Frag. Max. %	4.0	6.0	8.0 <sup>10/</sup>	
- Other Deleterious Max. %	4.0 <sup>11/</sup>	2.0	2.0 <sup>10/</sup>	
- Total Deleterious Max. %	5.0	6.0	10.0 <sup>10/</sup>	

- 1/ As modified by the Department.
- 2/ Does not apply to crushed concrete.
- 3/ For aggregate surface course, the maximum percent loss shall be 30.
- 4/ For portland cement concrete, the maximum percent loss shall be 45.
- 5/ Does not apply to crushed slag or crushed steel slag.
- 6/ For Class I Bituminous Binder Courses and Bituminous Base Course, except when used as Surface Course, the maximum percent loss shall be 45.
- 7/ Crushed concrete for all allowable Class C quality and Class D quality uses shall meet the Class C quality deleterious count, except the clay lump requirement shall not apply for Class C quality seal coat use and for all Class D quality uses.
- 8/ For crushed aggregate, if the material finer than the 75 µm (No. 200) sieve consists of the dust from fracture, essentially free from clay or silt, this percentage may be increased to 2.5.
- 9/ Does not apply to aggregates for Class I Binders, Class B Mixtures, and Bituminous Base Course Mixtures.
- 10/ Does not apply to Class A Seal and Cover Coats except when Note 7 applies.

- 11/ Includes deleterious chert. In gravel and crushed gravel aggregate, deleterious chert shall be the lightweight fraction separated in a 2.35 heavy media separation. In crushed stone aggregate, deleterious chert shall be the lightweight fraction separated in a 2.55 heavy media separation.

All varieties of chert contained in gravel coarse aggregate for portland cement concrete, whether crushed or uncrushed, pure or impure, and irrespective of color, will be classed as chert and shall not be present in the total aggregate in excess of 25 percent by mass (weight).

Aggregates used in handrail, parapet, end post, and all other superstructure concrete shall contain no more than two percent total by mass (weight) of deleterious materials or substances whose disintegration is accompanied by an increase in volume which may cause spalling of the concrete.

At the time of its use, the coarse aggregate shall be free from frozen material, material used to caulk rail cars, and all foreign material which may have become mixed with it during transportation and handling.

- (c) Gradation. The coarse aggregate shall be uniformly graded from coarse to fine and, when tested by means of laboratory sieves (square openings), shall conform to the designated gradation.

The sizes prescribed may be manufactured by any suitable commercial process and by the use of any sizes or shapes of plant screen openings necessary to produce the sizes within the limits of the sieve analysis specified.

The gradation numbers and corresponding gradation limits are listed in the following table and represent the limits which will determine suitability for use from all approved sources of supply. The gradation of the material from any one source shall be reasonably close to the gradation specified and shall not be subject to the extreme percentages of gradation represented by the tolerance limits for the various sieve sizes. The sizes are based on the use of square opening sieves in making analysis.

COARSE AGGREGATE GRADATIONS <sup>1/</sup>												
Sieve Size Percent Passing												
Grad No.	75 mm	63 mm	50 mm	37.5 mm	25 mm	19 mm	12.5 mm	9.5 mm	4.75 mm	1.18 mm	300 µm	75 µm <sup>2/</sup>
CA 1	100	95±5	60±15	15±15	3±3							
CA 2		100	95±5		75±15		50±15		30±10	20±15		8±4
CA 3		100	93±7	55±20	8±8		3±3					
CA 4			100	95±5	85±10		60±15		40±10	20±15		8±4
CA 5				97±3 <sup>3/</sup>	40±25		5±5		3±3			
CA 6				100	95±5		75±15		43±13	25±15		8±4
CA 7				100	95±5		45±15 <sup>4/</sup>		5±5			
CA 8				100	97±3	85±10	55±10		10±5	3±3 <sup>5/</sup>		
CA 9				100	97±3		60±15		30±15	10±10		6±6
CA 10					100	95±5	80±15		50±10	30±15		9±4
CA 11					100	92±8	45±15 <sup>6/</sup>		6±6	3±3 <sup>6/5/7/</sup>		
CA 12						100	95±5	85±10	60±10	35±10		9±4
CA 13						100	97±3	80±10	30±15	3±3 <sup>7/</sup>		
CA 14							90±10 <sup>8/</sup>	45±20	3±3			
CA 15							100	75±15	7±7	2±2		
CA 16							100	97±3	30±15	2±2 <sup>9/</sup>		
CA 17	100								65±20	45±20	20±10	10±5
CA 18	100				95±5				75±25	55±25	10±10	2±2
CA 19	100				95±5				60±15	40±15	20±10	10±5

COARSE AGGREGATE GRADATIONS <sup>1/</sup> (ENGLISH)												
Sieve Size Percent Passing												
Grad No.	3 in.	2 1/2 in.	2 in.	1 1/2 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	No. 4	No. 16	No. 50	No. 200 <sup>2/</sup>
CA 1	100	95±5	60±15	15±15	3±3							8±4
CA 2		100	95±5		75±15		50±15		30±10	20±15		
CA 3		100	93±7	55±20	8±8		3±3					
CA 4			100	95±5	85±10		60±15		40±10	20±15		8±4
CA 5				97±3 <sup>3/</sup>	40±25		5±5		3±3			
CA 6				100	95±5		75±15		43±13	25±15		8±4
CA 7				100	95±5		45±15 <sup>4/</sup>		5±5			
CA 8				100	97±3	85±10	55±10		10±5	3±3 <sup>5/</sup>		
CA 9				100	97±3		60±15		30±15	10±10		6±6
CA 10					100	95±5	80±15		50±10	30±15		9±4
CA 11					100	92±8	45±15 <sup>6/</sup>		6±6	3±3 <sup>6/5/7/</sup>		
CA 12						100	95±5	85±10	60±10	35±10		
CA 13						100	97±3	80±10	30±15	3±3 <sup>7/</sup>		
CA 14							90±10 <sup>8/</sup>	45±20	3±3			
CA 15							100	75±15	7±7	2±2		
CA 16							100	97±3	30±15	2±2 <sup>9/</sup>		
CA 17	100								65±20	45±20	20±10	10±5
CA 18	100				95±5				75±25	55±25	10±10	2±2
CA 19	100				95±5				60±15	40±15	20±10	10±5

- 1/ When an optional range is specified, once the range is selected, it shall not be changed.
- 2/ Subject to Maximum percent allowed in Coarse Aggregate Quality Table.
- 3/ Shall be 100 percent passing the 45 mm (1 3/4 in.) sieve.
- 4/ When using gradation CA 7 for A binder, the percent passing the 12.5 mm (1/2 in.) sieve may also be 35 10 or 15 10.
- 5/ When used in Class I Bituminous Mixtures, the percent passing the 1.18 mm (No. 16) sieve for gradations CA 8, CA 11, CA 13 or CA 16, shall be 4 4 percent.
- 6/ When using gradation CA 11 for B binder, the percent passing the 12.5 mm (1/2 in.) sieve may also be 15 10.
- 7/ The 1.18 mm (No. 16) requirement will be waived when CA 11 is used in the manufacture of portland cement concrete.
- 8/ 100 percent passing 16 mm (5/8 in.) sieve.

Note: When CA 7, CA 8, CA 11, CA 13, CA 14, CA 15, or CA 16 are used under paved median, notes 4, 5, 6, 7, and 8 shall apply.

- (d) Incompatibility. Incompatibility of any of the gradations or combinations of gradation permitted resulting in unworkable mixtures, nonadherence to the final mix gradation limits, or any other indication of incompatibility shall be just cause for rejection of one or both of the sizes.
- (e) Storage of Coarse Aggregate. Sites for stockpiles shall be grubbed and cleaned prior to storing the aggregates.

The stockpiles shall be built in layers not exceeding 1.5 m (5 ft) in height, and each layer shall be completely in place before the next layer is started. A stockpile may be expanded by again starting the expansion from the ground and building layers as before. End dumping over the sides will not be permitted. Steel track equipment will not be permitted on stockpiles of specified Class A Quality coarse aggregate. When loading out of stockpiles, vertical faces shall be limited to reasonable heights to eliminate segregation due to tumbling. Aggregate producer's stockpiling methods currently in use and proven satisfactory to the Engineer may be continued at the source. Segregation or degradation due to improper stockpiling or loading out of stockpiles shall be just cause for rejecting the material.

Separate stockpiles shall be provided for the various kinds of aggregates. Stockpiles shall be separated to prevent intermingling at the base. If partitions are used, they shall be of sufficient heights to prevent intermingling. Coarse aggregates for portland cement concrete and bituminous mixtures shall be handled in and out of the stockpiles in such a manner that will prevent contamination and degradation.

Crushed slag for portland cement concrete shall be stockpiled in a moist condition (saturated surface dry or greater) and the moisture content shall be maintained uniformly throughout the stockpile by periodic sprinkling.

**1004.02 Coarse Aggregate for Portland Cement Concrete.** The aggregate shall conform to the requirements of Article 1004.01 and the following specific requirements:

- (a) Description. The coarse aggregate shall be gravel, crushed gravel, crushed stone, crushed concrete, crushed slag or crushed sandstone.
- (b) Quality. The coarse aggregate shall be Class A quality.
- (c) Gradation. The gradations of coarse aggregate used in the production of portland cement concrete for pavements and structures shall be according to Table 1 of Article 1020.04. The sizes prescribed may be manufactured by any suitable commercial process. Washing equipment will be required where producing conditions warrant.
- (d) Combining Sizes. Each size shall be stored separately and care shall be taken to prevent them from being mixed until they are ready to be proportioned. The Contractor will be permitted to mix more than two sizes of coarse aggregate, provided the separate sizes selected and the proportions used in combining them are approved by the Engineer and that separate compartments are provided to proportion each size.

If the coarse aggregate is furnished in separate sizes, they shall be combined in proportions to provide a uniformly graded coarse aggregate grading within the following limits:

Class of Concrete <sup>1/</sup>  Combined Sizes		Percent Passing Sieves						
		63 mm	50 mm	45 mm	37.5 mm	25 mm	12.5 mm	4.75 mm
PV, PP and SH <sup>2/</sup>	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3
MS and SC <sup>2/</sup>	CA 3 & CA 7	100	95±5	---	---	55±25	20±10	3±3
	CA 3 & CA 11	100	95±5	---	---	55±25	20±10	3±3
	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3

Class of Concrete <sup>1/</sup>  Combined Sizes		(ENGLISH) Percent Passing Sieves						
		2 1/2 in.	2 in.	1 3/4 in.	1 1/2 in.	1 in.	1/2 in.	No. 4
PV, PP and SH <sup>2/</sup>	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3
MS and SC <sup>2/</sup>	CA 3 & CA 7	100	95±5	---	---	55±25	20±10	3±3
	CA 3 & CA 11	100	95±5	---	---	55±25	20±10	3±3
	CA 5 & CA 7	---	---	100	98±2	72±22	22±12	3±3
	CA 5 & CA 11	---	---	100	98±2	72±22	22±12	3±3

1/ See Table 1 of Article 1020.04.



2/ Any of the listed combination of sizes may be used.

- (e) Mixing Gravel, Crushed Gravel, Crushed Stone and Crushed Slag Coarse Aggregates. Two different specified sizes of crushed stone, gravel and crushed gravel from one source or any two sources may be combined in any consistent ratio in a mix, but the use of alternate batches of crushed stone, gravel or crushed gravel of any one size or combination of sizes will not be permitted. Coarse aggregates of any one size from different sources shall not be mixed without permission from the Engineer. Crushed slag shall not be combined or mixed with gravel, crushed gravel or crushed stone aggregates.
- (f) Freeze-Thaw Rating. When coarse aggregate is used to produce portland cement concrete pavement, base course, base course widening, shoulders, or the repair using concrete, the gradation permitted will be determined from the results of the Department's Freeze-Thaw Test. A list of freeze-thaw ratings for all A-quality coarse aggregate sources will be available. The gradations permitted for each rating shall be as follows:

Freeze-Thaw Rating (Top Size)		Gradation Permitted
mm	in.	
40 mm	(1 1/2 in.)	Combined CA 5 & CA 7, Combined CA 5 & CA 11, CA 7, or CA 11
25 mm	(1 in.)	CA 7, or CA 11
20 mm	(3/4 in.)	CA 11
13 mm	(1/2 in.)	CA 14
N.A.		Not Acceptable

Additional requirements may be placed on coarse aggregates when used in continuously reinforced concrete pavement. Such requirements will be stipulated on the most recent Freeze-Thaw Rating List.

### **1004.03 Coarse Aggregate for Bituminous Courses.**

- (a) Description. The coarse aggregate for all bituminous mixtures except Class I Surface Mixture E shall be crushed gravel, crushed stone (other than limestone), crushed sandstone, crushed slag, or chats. For Class I, Type 1 and 2 Surface Mixture E, the coarse aggregate shall be crushed slag, crushed steel slag, crushed sandstone, or a blend in equal proportions by volume of crushed slag, crushed steel slag or crushed sandstone with crushed gravel, chats, or a crushed stone other than limestone. Additional coarse aggregate for the other specific bituminous mixtures may also be used according to the following table:

Class	Use	Additional Coarse Aggregate Types Permitted
A	Seal or Cover	Gravel Crushed Concrete Crushed Steel Slag <sup>2/</sup> Limestone
B	Mixture	Gravel Crushed Concrete Limestone
I, Type 2	Mixture A	Limestone
I, Type 3	Mixture A	Limestone Novaculite Gravel
I, Type 1 and 2	Mixture B	Limestone
I, Type 3	Mixture B	Limestone Novaculite Gravel
I, Type 1 and 2	Mixture C	Crushed Steel Slag <sup>2/</sup> Limestone
I, Type 3	Mixture C	Limestone Novaculite Gravel
I, Type 1 and 2	Mixture D	Crushed Steel Slag Limestone <sup>1/</sup>

1/ Limestone may be used in Mixture D if blended in equal proportions by volume with crushed slag, crushed steel slag, crushed sandstone, or novaculite coarse aggregate.

2/ Crushed steel slag shall not be used when Mixture C is used as a leveling binder.

- (b) Quality. For Class A and B bituminous courses, the coarse aggregate shall be Class C quality or better. For Class I, Type 1, 2 and 3 surface courses and Class I, all types binder courses when used as surface course, the

coarse aggregate shall be Class B quality or better. For other courses, the coarse aggregate shall be Class C quality or better.

- (c) Gradation. The coarse aggregate gradations shall be as listed in the following table. For Class I mixtures, specified gradations other than those listed in the Table will be allowed if the Contractor provides a mix design indicating that all the mixture criteria stated in Section 406 will be met.

Class	Use	Gradation No.
A-1, 2 & 3	Seal 10 mm (3/8")	CA 16
A-1	Seal 13 mm (1/2")	CA 15
A-2 & 3	Cover	CA 14
B	Mixture	CA 6 <sup>1/</sup> or CA 10 <sup>1/</sup>
I Type 2 & 3	Mixture A	CA 7 <sup>2/</sup> or CA 8 <sup>3/</sup>
I Type 1, 2 & 3	Mixture B	CA 11 <sup>4/</sup>
I Type 1, 2 & 3	Mixture C, D & E	CA 13 <sup>5/</sup> or CA 16

- 1/ In Class B Mixture aggregate where the aggregates are deficient in fines, the material added to compensate shall not be soil materials such as clay, loam or silt. The material added to make up deficiencies shall be a granular material approved by the Engineer. Plasticity Index of Class B Mixture material shall not exceed four.

Gradation CA 12 may be used in lieu of CA 6 or CA 10, when specified. When lifts of nominal 45 mm (1 3/4 in.) or less compacted thickness are placed, Gradations CA 10 or CA 12 shall be used. The required gradation may be obtained by blending aggregates of Class C Quality or better. The gradation of the individual aggregates shall be approved by the Engineer. When the aggregates are blended, aggregate feeders for each size shall be provided according to Article 1102.01(d). If Mineral Filler is used, the mineral filler equipment requirements under Article 1102.01(d)(5) or (d)(9) shall apply.

- 2/ When directed by the Engineer, CA 13 or CA 16 shall be blended with CA 7 for Class I Types 2 and 3, Mixture A.
- 3/ Gradation CA 8 for Class I Mixture A may, at the option of the Contractor, be obtained by blending either gradation CA 7 or CA 7 (as modified in Article 1004.01(c), Note 4) with CA 13 or CA 16.
- 4/ When directed by the Engineer, CA 13 or CA 16 shall be blended with CA 11 for Class I, Types 1, 2, and 3, Mixture B.
- 5/ Gradation CA 16 shall be used in lieu of CA 13 when the bituminous course is designed for 30 mm (1 1/4 in.) or less in thickness.

- (d) Sources of Supply. All sources of supply shall be approved by the Engineer. The Contractor shall submit to the Engineer a statement giving the sources of the coarse aggregate. Only coarse aggregates from these sources shall be used on the job unless approval in writing is obtained from the Engineer.

**1004.04 Coarse Aggregate for Aggregate Surface Course, Granular Embankment Special, Aggregate and Stabilized Aggregate Base, Subbase and Shoulder Courses.** The aggregate shall conform to the requirements of Article 1004.01 and the following:

- (a) Description. The coarse aggregate shall be pit run gravel, gravel, crushed gravel, novaculite, crushed stone, crushed concrete, crushed slag or crushed sandstone, except that pit run gravel and gravel shall not be used for subbase Granular Material, Type C.

The granular material for stabilized aggregate base, subbase, and shoulder courses, if approved by the Engineer, may be produced by blending aggregates from more than one source, provided the method of blending results in a uniform product. The components of a blend need not be of the same kind of material. The source of material shall not be changed during the progress of the work without written permission from the Engineer. Where a natural aggregate is deficient in fines, the material added to make up deficiencies shall be a material approved by the Engineer.

- (b) Quality. The coarse aggregate shall be Class D Quality or better.
- (c) Gradation. The coarse aggregate gradation shall be used as follows:

For aggregate surface course Type B, Gradation CA 6, CA 9, or CA 10 may be used. If approved by the Engineer, Gradation CA 4 or CA 12 may be used.

For aggregate subbase Type B, Gradation CA 6, CA 10, CA 12, or CA 19 shall be used. If approved by the Engineer, Gradation CA 2 or CA 4 may be used.

For aggregate subbase Type C, Gradation CA 7 as specified in Article 1004.01 or combined size CA 5 and CA 7 as specified in Article 1004.02 shall be used. If separate sizes are furnished, combining by proper mixing will be required either at the source or at the jobsite.

For granular aggregate courses (base, subbase, and shoulder except subbase Types B and C), Gradation CA 6 or CA 10 shall be used. If specified, Gradation CA 2 or CA 4 may be used in lieu of CA 6 or CA 10.

Stabilized aggregate courses (base, subbase, and shoulder), Gradation CA 6, or CA 10 shall be used. If specified, Gradations CA 2, CA 4, or CA 12 may be used in lieu of CA 6 or CA 10.

For Aggregate Surface Course, Type A and granular embankment special, CA 6 or CA 10 shall be used. If approved by the Engineer, Gradation CA 2, CA 4, CA 9, or CA 12 may be used in lieu of CA 6 or CA 10.

- (d) Plasticity. All material shall comply with the plasticity index requirements listed below. The plasticity index requirement for crushed gravel, crushed stone and crushed slag may be waived if the ratio of the percent passing the 75  $\mu\text{m}$  (No. 200) sieve to that passing the 425  $\mu\text{m}$  (No. 40) sieve is 0.60 or less.

Type of Construction	<u>Plasticity Index - Percent</u> <sup>1/</sup>	
	Gravel	Crushed Gravel, Stone & Slag
Granular Embankment, Special	0 to 6	0 to 4
Aggregate Subbase Type A	0 to 9	.....
Type B	0 to 9	.....
Aggregate Shoulders Type A	2 to 9	.....
Type B	2 to 9	.....
Aggregate Base Course Type A	0 to 6	0 to 4
Type B	0 to 6	0 to 4
Aggregate Surface Course Type A	2 to 9	.....
Type B <sup>2/</sup>	2 to 9	.....
Stabilized Aggregate Mat'l.	0 to 9	0 to 9

1/ Plasticity Index shall be determined by the method given in AASHTO T 90. Where shale in any form exists in the producing ledges, crushed stone samples shall be soaked a minimum of 18 hours before processing for plasticity index or minus 425  $\mu\text{m}$  (No. 40) material. When clay material is added to adjust plasticity index, the clay material shall be in a minus 4.75 mm (No. 4) sieve size.

2/ When Gradation CA 9 is used, the plasticity index requirement will not apply.

**1004.05 Coarse Aggregate for Membrane Waterproofing.** The aggregate shall conform to the requirements of Article 1004.01 and the following specific requirements:

- (a) Description. The coarse aggregate shall be gravel, crushed gravel, crushed stone, crushed concrete, crushed slag, crushed sandstone or chats.
- (b) Quality. The coarse aggregate shall consist of tough durable particles reasonably free of objectionable material and, when subjected to five cycles of the sodium sulphate soundness test (AASHTO T 104), the weighted average loss shall not be more than 15 percent.
- (c) Gradation. The coarse aggregate shall be Gradation CA 16.

**1004.06 Coarse Aggregate for Blotter, Embankment, Backfill, and French Drains.** The aggregate shall conform to the requirements of Article 1004.01 and the following specific requirements:

- (a) Description. The coarse aggregate shall be gravel, crushed gravel, pit run gravel, crushed stone, crushed concrete, crushed slag, chats, crushed sandstone or wet bottom boiler slag.
- (b) Quality. The coarse aggregate shall consist of sound durable particles reasonably free of objectionable deleterious material.
- (c) Gradation. The coarse aggregate gradation shall be as follows:

Blotter.....	CA 15
Nonporous Granular Embankment and Backfill.....	CA 17
Porous Granular Embankment and Backfill, and French Drains.....	CA 18

**1004.07 RAP Materials.** RAP material is reclaimed asphalt pavement material resulting from the cold milling or crushing of an existing hot-mix bituminous concrete pavement structure. Original pavement materials shall be crushed coarse aggregate of Class C quality (Class B quality for Surface Course), or better. The Contractor shall inform the Engineer as to the location of the originally placed pavement and/or the origin of existing stockpiled RAP prior to being used.

Any RAP that cannot be readily broken down in the mixing process and/or affects paving operation shall be processed over a "grizzly" prior to introduction into the mixture. All over sized aggregates in the RAP shall be reduced to the maximum size permitted for the mixture being produced.

The blending proportions may be changed during the progress of the job with prior approval of the Engineer.

RAP stockpiles shall be separated by type of aggregate (crushed natural aggregate, steel slag, or blast furnace slag). RAP containing contaminants, such as earth, brick or sand, will be unacceptable until the contaminants are thoroughly removed. Sheet Asphalt shall be stockpiled separately. The Contractor may provide

documented quality control information, satisfactory to the Engineer, that defines the gradation and asphalt content of a processed stockpile.

Note: RAP containing high percentages of volatile petroleum solvents may be a fire or explosion hazard when heated.

## **SECTION 1005. STONE, CONCRETE BLOCKS AND BROKEN CONCRETE FOR EROSION PROTECTION, SEDIMENT CONTROL, AND ROCKFILL**

**1005.01 Stone for Erosion Protection, Sediment Control, and Rockfill.** Stone, sediment, and rockfill shall meet the following requirements:

- (a) Description. The material shall be stone quarried from undisturbed, consolidated deposits of rock reasonably free of shale and shaly stone. The ledges shall be sufficiently thick to produce the desired dimensions. The stone shall be reasonably free of laminations, seams, cracks and other structural defects or imperfections tending to destroy its resistance to weather. Field stone or boulders will not be accepted. Bedding material shall be crushed stone, crushed gravel, crushed sandstone, or crushed slag. The crushed slag shall meet the Department's "Test for Leachate".
- (b) Quality. Stone for erosion protection, sediment control or rockfill shall be quarried from ledges meeting one of the listed quality designations. All ledges shall be sufficiently thick to produce the desired dimensions. Ledges shall be checked with rock samples sized to CA-7/11 and run in the IDOT sodium sulfate soundness test. Bedding material shall be tested in its manufactured gradation in the Department's sodium sulfate soundness test.

<u>Quality Designation</u>	<u>Definition</u>
--------------------------------	-------------------

- |   |  |
|---|--|
| A | The stone shall not exceed 15 percent sodium sulfate soundness loss. Elongated pieces (length is greater than five times Average thickness) shall not exceed 10 percent by weight. The stone shall have a specific gravity (dry) greater than 2.45 when checked in a full gradation product. |
| B | The stone shall not exceed 25 percent sodium sulfate soundness loss. Elongated pieces ( length is greater than five times average thickness) shall not exceed 10 percent by weight.  |
| C | The stone shall only have to conform to the above paragraph (a), Description.  |

- (c) Gradation. Stone for erosion protection or sediment control shall meet one of the gradation number designations listed in the following table. All gradations produced shall be well graded. A minimum of one gradation check for each gradation produced shall be run during initial production each year. Additional checks may be done by visual inspection if no gradation problem exists.

BEDDING MATERIAL					
Sieve Size Percent Passing					
GRAD. NO.	100 mm	75 mm	50 mm	37.5 mm	4.75 mm
1		100		53±23	8±8
2	100		53±23		8±8

BEDDING MATERIAL (ENGLISH)					
Sieve Size Percent Passing					
GRAD. NO.	4 in.	3 in.	2 in.	1 1/2 in.	No. 4
1		100		53±23	8±8
2	100		53±23		8±8

EROSION PROTECTION, SEDIMENT CONTROL, AND ROCKFILL														
Rock Size (kg) Percent Passing														
Grad. No.	455 <sup>1/</sup>	270 <sup>1/</sup>	180 <sup>1/</sup>	135	75	70 <sup>1/</sup>	40	20 <sup>1/</sup>	18	5	4	3	1	0.5
3 <sup>2/</sup>								100			50±20			8±8
4		100			100				50±20					8±8
5							50±20						8±8	
6		100			50±20								8±8	
7	100			50±20							8±8			



EROSION PROTECTION, SEDIMENT CONTROL, AND ROCKFILL (ENGLISH)															
Rock Size (lb)															
Percent Passing															
Grad.	No.	1000 <sup>1/</sup>	600 <sup>1/</sup>	400 <sup>1/</sup>	300	170	150 <sup>1/</sup>	90	50 <sup>1/</sup>	40	12	10	6	3	1
3 <sup>2/</sup>									100			50±20			8±8
4							100			50±20					8±8
5			100					50±20							8±8
6		100				50±20								8±8	
7	100				50±20						8±8				

- 1/ Five percent by weight may be oversize. Each oversize piece shall not exceed the maximum size of the gradation by more than 20 percent.
  - 2/ When used for aggregate ditch check, Gradation 3 may be modified as follows: Percent Passing: 20 kg (50 lb) - 100; 1.5 kg (3 lb) - 50±20; 0.5 kg (1 lb) - 8±8.
- (d) Usage. Stone for use as erosion protection and sediment control shall be designated by class. The class shall be a combination of a quality designation and a gradation designation. The various uses with their allowable classes shall be specified by the designer according to the latest Bureau of Materials and Physical Research policy memorandum.

Rockfill shall meet Quality Designation #C and may be shot rock, primary crusher run, or other specified gradations.

#### **1005.02 Concrete Blocks, Broken Concrete, and Concrete Mats for Riprap.**

The concrete blocks shall be cast solid; shall be made from aggregates meeting all requirements for physical properties, soundness, and wear specified in Articles 1003.02 and 1004.02 and shall contain not less than 340 kg (565 lb) of portland cement per cubic meter (cubic yard) of concrete. The concrete shall have a minimum compressive strength of not less than 24,000 kPa (3500 psi) at the age of 14 days, as determined by the Engineer, either from tests of entire blocks or from tests of blocks subdivided by sawing or drilling into prisms or cylinders. Specimens for testing will be selected by the Engineer at such intervals as will ensure control of the production of blocks. The blocks may be made from plastic concrete, or they may be machine made, utilizing the type of equipment ordinarily employed in the fabrication of building blocks.

- (a) Blocks Produced from Plastic Concrete. The blocks shall be made from concrete containing not less than 4.0 nor more than 7.0 percent entrained air and having a slump of not more than 40 mm (1 1/2 in.). The concrete shall be consolidated in the molds by vibratory equipment and in a manner meeting the approval of the Engineer. The blocks shall be finished to uniform and true dimensions.
- (b) Machine Made Blocks. The concrete shall be made with aggregate sizes and of a consistency suitable for production of the blocks by machine

methods. The concrete shall have an air-entrainment (Note 1) meeting the approval of the Engineer. The blocks shall be of uniform and true dimensions.

Note 1. The experience in the manufacture, inspection and use of machine made blocks for riprap is very limited. It is known that air-entrained concrete of the type and consistency suitable for manufacture of the blocks will also contain entrapped air. Available test methods do not differentiate between the two, and some experimentation may be necessary at the beginning of the production. Manufacturers in general have had little experience in the manufacture of blocks from mixtures having cement contents as high as specified herein, and some adjustment of the usual proportion of fine to coarse aggregate may be required, in order that the equipment may work satisfactorily.

- (c) Size of Blocks. The concrete blocks shall conform, to the minimum dimensions, 200 mm x 200 mm x 400 mm (8 in. x 8 in. x 16 in.) concrete building block.
- (d) Broken Concrete. The material shall be made from newly broken, sound concrete pavement or other suitable concrete debris from demolished concrete construction having a minimum thickness of 150 mm (6 in.) between unbroken surfaces. Concrete showing excessive popping, spalling, cracking or any other type of disintegration indicating poor resistance to weathering will not be acceptable. No reinforcing steel or other such material shall be protruding from the broken pieces. The gradation or sizing of the pieces shall conform to Article 1005.01(c).
- (e) Concrete Mats. Concrete mats shall be made from plastic concrete. Concrete mats shall consist of a grid of interconnected concrete blocks of sufficient size to meet or exceed the unit weight required in the hydraulic design. The blocks in the mat shall be connected by cast-in-place stainless steel cables of sufficient size and strength to maintain the structural integrity of the mat throughout its design life. The mats shall be supplied with a filter fabric meeting the requirements of Section 282 permanently attached to the bottom of the blocks without the use of adhesives. The dimensions of the filter fabric shall exceed the mat dimensions by an amount equal or greater than the recommended overlap width. Individual mats shall be tied together using corrosion resistant clamps recommended by the mat manufacturer. The mats shall be anchored at the frequency and depth required in the hydraulic design using approved anchors.

## SECTION 1006. METALS

**1006.01 Corrugated Steel Pipe and Corrugated Steel Pipe Arch.** The thickness and masses for different covers shall be as specified in Tables I B and II A of Article 542.03.

- (a) Corrugated Steel Culvert Pipe and Corrugated Steel Pipe Arch. The pipe and arch shall conform to the requirements of AASHTO M 36M (M 36).

Helically Corrugated Steel Culvert Pipe. The sawed or torch cut ends of helically corrugated steel culvert pipe shall be coated with a zinc metallizing process, aluminum asphalt paint or other methods approved by the Engineer. Helically corrugated steel culvert pipe shall conform to the requirements of AASHTO M 36M (M 36), except that all fabrication weld repairs shall meet the weld seam tolerance. No damage shall be repaired or painted without prior approval of the Engineer. Welded helically corrugated pipe that has two rows of circumferential corrugations fabricated on each end may be field connected with an approved hugger type band.

- (b) Bituminous Coated Corrugated Steel Culvert Pipe and Bituminous Coated Corrugated Steel Pipe Arch. This pipe and pipe arch shall conform to the requirements of AASHTO M 190, Type A. Bituminous coating for the connecting bands will not be required. Any bituminous coating damaged in shipment, during installation, or prior to final acceptance shall be repaired by the Contractor to the satisfaction of the Engineer.
- (c) Precoated Galvanized Corrugated Steel Culvert Pipe and Precoated Galvanized Corrugated Steel Pipe Arch. The precoated steel sheets used to fabricate these items shall conform to AASHTO M 246M (M 246), Grade 10/3. The precoated culvert pipe and pipe arch shall conform to the requirements of AASHTO M 245M (M 245), except that the sheet thickness for the respective diameters of pipe and fill heights shall be as specified in Tables IB and IIA of Article 542.03. The sawed ends of helically corrugated pipe shall be coated with a zinc metallizing process, aluminum asphalt paint or other methods approved by the Engineer. Precoating for the connecting bands will not be required.
- (d) Perforated Corrugated Steel Pipe. This pipe shall conform to the requirements of AASHTO M 36M (M 36) except that when a fine aggregate backfill is used, perforations shall have a nominal diameter of 5 mm (3/16 in.).
- (e) Precoated Fully Lined Galvanized Corrugated Steel Pipe and Precoated Fully Lined Galvanized Corrugated Steel Pipe Arch. This pipe and arch shall meet the requirements as specified in (c) above except that coupling bands shall be precoated and shall be of the hugger or annular type. Additionally, the entire interior of the pipe or arch shall be covered with a centrifugally applied lining having a minimum thickness of 3 mm (1/8 in.) above the crests of the inside corrugations. When rivets are used in the fabrication of the pipe or arch, they shall be located in the valleys of the corrugations inside the pipe or arch. The lining material shall conform to AASHTO M 190 unless otherwise permitted, and the surface of the lining shall be smooth and uniform.
- (f) Precoated PVC Lined Galvanized Corrugated Steel Pipe. The precoated steel sheets used to fabricate this pipe shall conform to AASHTO M 246M (M 246), Type A, with the polymeric coating on the outside of the pipe. The pipe shall have two annular corrugations and a 15 mm (1/2 in.) upturned flange square with the longitudinal axis of the pipe at each end of each length of pipe. The PVC liner shall be a minimum of 1 mm (0.055 in.) thick and shall conform to ASTM D 1784 cell class 13343-B. Longitudinal seams

shall have a minimum 50 mm (2 in.) single lap, and circumferential seams shall be butt joints with a minimum 25 mm (1 in.) wide backup strip of the same material. All seams shall be chemically welded and the ends of the PVC liner shall be bent to form a flange which is adhesive cemented to the steel pipe flange at each end of each length of pipe. The annular space between the steel pipe shell and the PVC liner shall be filled with a closed cell urethane foam conforming to ASTM D 2341 cell class 3306669883 which when foamed in place has a minimum density of 32 kg/cu m (2 lb/cu ft). Coupling bands shall be precoated and shall be of the flange type. Gaskets shall meet the requirements of ASTM F 477 and shall be capable of meeting the leakage requirements of ASTM C 443M (C 443).

- (g) **Precoated Smooth Lined Corrugated Steel Pipe and Precoated Smooth Lined Corrugated Steel Pipe Arch.** This pipe or arch shall conform to AASHTO M 246M (M 246) except that the steel sheet used shall be coated with a polymer coating of 0.25 mm (0.010 in.) minimum thickness on the exposed faces of both the outer shell and the inner liner. The outer shell and the inner liner shall be lock seamed together or otherwise attached integrally to each other at helical seams spaced not more than 750 mm (30 in.) apart. The pipe or arch shall have two annular corrugations and a 15 mm (1/2 in.) upturned flange square to the longitudinal axis of the pipe or arch at each end of each length of pipe or arch. Coupling bands shall be precoated and shall be of the channel type. Gaskets shall meet the requirements of ASTM F 477, shall totally cover the peripheries of abutting flanges and shall be capable of meeting the leakage requirements of ASTM C 443M (C 443). The mass per meter (foot) of precoated smooth lined corrugated steel pipe or arch shall not be less than the mass per meter (foot) of a standard corrugated steel pipe or arch of the steel thickness shown in Article 550.03. The inner liner shall have a minimum thickness of 1 mm (0.040 in.) and the outer shell shall have a minimum thickness of 60 percent of the steel thickness shown in Article 550.03.
- (h) **Zinc and Aramid Fiber Composite Coated Corrugated Steel Pipe.** Zinc and aramid fiber composite coated corrugated steel pipe shall conform to the requirements of AASHTO M 36M (M 36).
- (i) **Aluminized Steel Type 2 Corrugated Culvert Pipe and Corrugated Pipe Arch.** This Pipe shall conform to AASHTO M 274 and M 36.

### **1006.02 Corrugated Structural Plate Pipe, Pipe Arches, and Arches.**

Corrugated steel structural plate pipe, pipe arches and arches that are fabricated and erected in sections shall conform to the requirements of AASHTO M 167M (M 167). Corrugated aluminum alloy structural plate pipe, pipe arches and arches that are fabricated and erected in sections shall conform to the requirements of AASHTO M 219M (M 219).

**1006.03 Corrugated Aluminum Alloy Pipe and Corrugated Aluminum Alloy Culvert Pipe Arch.** These Specifications cover corrugated aluminum alloy culvert pipe, bituminous coated corrugated aluminum alloy culvert pipe, corrugated aluminum alloy culvert pipe arch, bituminous coated corrugated aluminum alloy culvert pipe arch, helically corrugated aluminum alloy culvert pipe, perforated corrugated

aluminum alloy pipe and semicircular aluminum alloy pipe. The thickness for different depths of cover shall be as specified in Table I C and Table II A of Article 542.03.

- (a) Corrugated Aluminum Alloy Culvert Pipe and Corrugated Aluminum Alloy Culvert Pipe Arch. The pipe or arch shall conform to the requirements of AASHTO M 196M (M 196), except the lot number may be shown instead of the processing date.
- (b) Bituminous Coated Corrugated Aluminum Alloy Culvert Pipe and Bituminous Coated Corrugated Aluminum Alloy Culvert Pipe Arch. The coating for the pipe or arch shall conform to the requirements of AASHTO M 190 Type A.

The uncoated pipe shall conform to Article 1006.03(a). Bituminous coating for the connecting bands will not be required.

- (c) Helically Corrugated Aluminum Alloy Culvert Pipe. This pipe may be used as an alternate and shall conform to the requirements of AASHTO M 196M (M 196), except as follows:

Pipe having a diameter of 250 mm (10 in.) or less shall have corrugations not less than 35 mm (1 3/8 in.) nor more than 48 mm (1 7/8 in.) center-to-center, measured at right angles to the direction of the corrugations and shall have a depth of not less than 6 mm (1/4 in.).

Pipe having a diameter of 300 mm (12 in.) or greater shall have corrugations not less than 48 mm (1 7/8 in.) nor more than 70 mm (2 3/4 in.) center-to-center, measured at right angles to the direction of the corrugations. Pipe having diameters of not less than 300 mm (12 in.) nor more than 525 mm (21 in.) shall have corrugation depth of not less than 11 mm (7/16 in.). Pipe having diameters greater than 525 mm (21 in.) shall have corrugation depth of not less than 13 mm (1/2 in.). Pipe with helical corrugations shall have a continuous lock seam extending from end to end of each length of pipe. The seams shall be fabricated in such a manner that they will not affect the shape or nominal diameter of the pipe, and so they will not create an element of weakness in the pipe.

- (d) Perforated Corrugated Aluminum Alloy Pipe. This pipe shall conform to the requirements of AASHTO M 196M (M 196), except the lot number may be shown instead of the processing date and perforations shall have a nominal diameter of 5 mm (3/16 in.).

**1006.04 Structural Steel.** Structural steel shall conform to the requirements of AASHTO M 270M Grade 250 (M 270 Grade 36), except bar stock conforming to ASTM A 576 Special Quality Steel with similar mechanical properties and chemical composition, may be used.

- (a) Rollers. Rollers may be made from any of the following materials:
  - (1) Structural steel having a minimum tensile strength of 400,000 kPa (58,000 psi), a minimum yield point of 250,000 kPa (36,000 psi), a minimum elongation of 20 percent, and conforming in all other respects to AASHTO M 270 Grade 36.

- (2) Rollers, 225 mm (9 in.) or less in diameter, may be made from cold finished bars conforming to AASHTO M 169, Grades 1016 to 1030 inclusive.
- (3) Forgings shall conform to the requirements of AASHTO M 102, Class C.
- (b) Steel Posts, Blockouts, Restraints and Wire Rope for Guardrail. Steel posts and blockouts shall conform to the requirements of AASHTO M 270M Grade 250 (M 270 Grade 36) or ASTM A 769M Grade 250 or 280 (A 769 Grades 36 or 40), except when "C" shape posts and blockouts for guardrail are used, they shall conform to the requirements of AASHTO M 270M Grade 250 (M 270 Grade 36) or ASTM A 570M Grade 250 or 280 (A 570 Grades 36 or 40), with a maximum tensile strength of 550,000 kPa (80,000 psi). Steel restraints shall conform to the requirements of AASHTO M 227M Grade 485 through 555 (M 227 Grades 70 through 80). Steel posts and restraints shall be galvanized according to AASHTO M 111. Wire rope for cable assemblies shall be according to AASHTO M 30, Class A coating.
- (c) Pins. Pins shall conform to SAE 8620 Material.

**1006.05 Metal Shell and Sheet Piling.** Metal shell and sheet piling shall conform to the following:

- (a) Metal Shell Piling. All shells without taper shall conform to the requirements of ASTM A 252. The steel for fluted, tapered shells shall have a minimum tensile strength of 345,000 kPa (50,000 psi).
- (b) Sheet Piling. Steel sheet piling shall be of the size and shape as specified on the plans and conform to the requirements of AASHTO M 202M (M 202).

**1006.06 Transverse Tie Rods and Dowel Rods.** Transverse tie rods and dowel rods shall conform to the following:

- (a) Transverse Tie Rods. Steel for transverse tie rods shall conform to the requirements of AASHTO M 227M Grade 485 through 555 (M 227 Grades 70 through 80), AASHTO M 31M (M 31) or M 53M (M 53) plain bars. After fabrication, the transverse tie assemblies (tie rods, nuts, washers and sleeves) shall be hot-dipped galvanized according to AASHTO M 232. The small articles may be zinc-coated by the mechanically deposited process conforming to AASHTO M 298, Class 50. The thickness of the mechanical galvanizing shall not exceed 150  $\mu$ m (6 mils).
- (b) Dowel Rods. Steel for dowel rods shall conform to the requirements of AASHTO M 227M Grades 485 through 555 (M 227 Grades 70 through 80), AASHTO M 31M (M 31) or M 53M (M 53).

**1006.07 Turned and Ribbed Bolts.** Low carbon steel turned and ribbed bolts shall conform to the requirements of ASTM A 307, Grade C.

**1006.08 High Strength Steel Bolts, Nuts, and Washers.** High strength steel bolts, nuts and washers shall conform to the requirements of AASHTO M 164M (M 814

164), except as modified by the Specifications for Structural Joints using AASHTO M 164M (M 164) Bolts, approved by the Research Council on Structural Connections of the Engineering Foundation.

When galvanizing is specified, the zinc coating shall be by the mechanical plating method conforming to AASHTO M 298, Class 50. The thickness of the mechanical galvanizing shall not exceed 150  $\mu\text{m}$  (6 mils). Zinc-coated nuts shall be tapped oversize according to the requirements of AASHTO M 291M (M 291) and shall meet the supplementary requirements of S1.1 thru S1.2.1 of the same specifications for lubricant and testing. The lubricant shall be tinted to produce a distinct contrast with the nut.

**1006.09 Anchor Bolts and Rods.** All headed anchor bolts, non-headed anchor rods, and nuts shall conform to ASTM A 307 Grade C, ASTM F1554 Grade 250 (Grade 36), AASHTO M 270M, Grade 250 (M 270, Grade 36), AASHTO M 31M (M 31) or AASHTO M 53M (M 53) with a maximum tensile strength of 655,000 kPa (95,000 psi).

All anchor bolts shall be of the type and dimensions as shown on the plans. The minimum bend radius shall be four times the nominal diameter. Expansion hook bolts, which are to be used as dowels, shall contain an approved anchoring device providing the following minimum certified proof load according to tensile testing requirements of ASTM E 488 for the specified hook bolt diameter:

<u>HOOK BOLT</u>	<u>PROOF LOAD</u>
M16 (5/8 in.)	22 kN (5000 lb)
M 20 (3/4 in.)	33 kN (7500 lb)
M 22 (7/8 in.)	35 kN (8000 lb)

Anchor bolts and rods, nuts and washers conforming to AASHTO M 314 or ASTM F 1554 shall satisfy the applicable specification for the grade specified and the supplemental Charpy V-Notch(CVN) toughness requirements herein specified. Grade 250 (Grade 36) and Grade 380 (Grade 55) anchor bolts and rods shall satisfy Supplemental Requirement S4 and Table S1.1 of ASTM F 1554. Grade 725 (Grade 105) anchor bolts and rods shall satisfy Supplemental Requirement S5 and Table S1.2 of ASTM F 1554.

Unspecified welding of anchor bolts and rods shall only be permitted by a written approval of the Engineer.

Anchor bolts and rods, nuts and washers requiring galvanizing shall be completely coated by either the hot-dipped process conforming with AASHTO M 232, the mechanical plating method conforming to AASHTO M 298, Class 50 with a maximum coating thickness of 150  $\mu\text{m}$  (6 mils) or the electrolytic process according to ASTM F 1136.

Non-headed anchor bolts shall be galvanized for a minimum length of 300 mm (12 in.) from the threaded end.

**1006.10 Concrete Reinforcement Bars, Fabric, and Strand.**

- (a) General Conditions. All fabrication shall be done at the mill or shop prior to shipment.

No substitutions shall be made without the approval of the Engineer. Approval shall be obtained before the bars or fabric are fabricated or ordered. At the time of shipment, the surface of all reinforcement bars, fabric, and prestressing strands shall be free from loose mill scale, dirt, oil, grease, or other foreign substances. A light coating of rust, which may form during storage under acceptable conditions at the mill or warehouse, will not be deemed cause for rejection. Stocks of reinforcement bars, fabric, or strand either at the mill or warehouse, which have not been protected in an adequate manner during storage, will not be accepted.

At the time the bars and fabric are placed in the work, they shall be free from rust which pits the surface or scales off, dirt, oil, grease or other foreign substances. A light coating of rust, which may form during storage on the work under acceptable conditions, will not be deemed cause to require cleaning. Thin powdery rust and tight rust is not considered detrimental and need not be removed.

- (b) Reinforcement Bars.

- (1) General. Reinforcement bars, including epoxy coated reinforcement bars, shall conform to the requirements of AASHTO M 31M (M 31) or M 53M (M 53), Grade 300 (40) or 400 (60), or AASHTO M 42M (M 42), Grade 400 (60) deformed bars. In addition to the other requirements in AASHTO M 31M (M 31), bars larger than No. 35 (No. 11) that are to be bent shall comply with the requirements for Bending Properties of AASHTO M 31M (M 31). For these bend tests requirements, the diameter of the pin shall be nine times the diameter of the specimen, and the bend shall be 90 degrees. Bars fabricated by the producer according to AASHTO M 42M (M 42) shall comply with the bend test requirements of AASHTO M 42M (M 42). The Bending Requirements of AASHTO M 42M (M 42) will not apply when rail steel bars are used for longitudinal bars in continuously reinforced concrete pavement. Spiral reinforcement for concrete columns and concrete piers shall be deformed or plain bars conforming to the requirements of AASHTO M 31M (M 31), M 42M (M 42) or M 53M (M 53), or cold-drawn steel wire conforming to AASHTO M 32.

Longitudinal bars for continuously reinforced concrete pavement shall be AASHTO M 31M (M 31), M 42M (M 42) or M 53M (M 53) Grade 400 (60) deformed bars. The transverse bars may be either AASHTO M 31M (M 31) or M 53M (M 53), Grade 300 (40) or Grade 400 (60) deformed bars, except that transverse bars to which chairs are to be welded, the bars across the longitudinal joint, and bars which are to be bent shall be Grade 300 (40), except the elongation shall not be less than 20 percent for bent bars straightened in the field.



- (2) Epoxy Coated Reinforcement Bars. Epoxy coated reinforcement bars shall conform to the requirements of AASHTO M 284M (M 284), except that the maximum thickness of epoxy coating on spiral reinforcement, coated after fabrication, shall be 0.5 mm (20 mils).

Coating material shall be any one of the epoxy resin powders which have been prequalified by the National Bureau of Standards and approved by the Engineer.

Bars may be sheared or sawn to length after coating, provided end damage to coating does not extend more than 15 mm (1/2 in.) back and the cut end is patched before any visible oxidation appears. Flame cutting will not be permitted.

The coating applicator shall furnish to the Engineer at the time of shipment written certification that the coated reinforcement bars were cleaned, coated, and tested according to the requirements of AASHTO M 284M (M 284).

In addition to the requirements of AASHTO M 284M (M 284) for continuity of coating, no more than eight of the holidays permitted shall be in any 300 mm (1 ft) length of bar.

- (c) Reinforcement Fabric for Portland Cement Concrete Pavement.

- (1) Welded Wire Fabric. Welded wire fabric shall conform to the requirements of AASHTO M 55. Welded wire fabric for concrete pavement may be furnished in either flat sheets or hinged sheets. The method of hinging the sheets shall meet the approval of the Engineer.
- (2) Bar Mat Fabric. Bar mat fabric shall conform to the requirements of AASHTO M 54M (M 54). Longitudinal bars shall be Grade 60. The fabric shall be furnished either in flat sheets or hinged flat sheets.

- (d) Prestressing Steel Strand. Prestressing steel strand shall conform to the requirements of AASHTO M 203.

#### **1006.11 Pavement Longitudinal Metal Joints, Dowel Bars, Expansion Joint Assembly, and Contraction Joint Assembly.**

- (a) Pavement Longitudinal Metal Joint, Pins and Bar Supports. Longitudinal metal joint for pavement, pins for installing the joint and supports for bars in pavement shall be as specified.
- (b) Dowel Bars. Dowel bars shall be plain, round bars conforming to the requirements of AASHTO M 227M Grades 485 through 555 (M 227 Grades 70 through 80). The finished bars shall be saw cut and free from burrs or out-of-round ends which will prevent their slipping easily in the concrete. The bars shall be epoxy coated according to the requirements of AASHTO M 254.

- (c) Expansion Joint Assembly. The expansion joint assembly shall be an approved welded assembly utilizing wire sizes corresponding to the requirements for contraction joint assemblies and shall have a joint width conforming to the requirements shown on the plans.
- (d) Contraction Joint Assembly. The contraction joint assembly shall be an approved welded assembly possessing the rigidity to hold the epoxy coated dowel bar during the placing and compacting of the concrete to the degree of alignment specified. The assembly shall have two parallel spacer bars and two subgrade bearing members. An upright bar support of each end of each dowel bar shall be welded to both the spacer bar and the bearing member at appropriate points to hold the bars at the design height.

The epoxy coated dowel bars shall be spaced as shown on the plans. The alternate ends of epoxy coated dowel bars shall be welded to the spacer bars or the upright bar. Weld areas need not be patched with epoxy. One weld is permitted per dowel bar. The end of each dowel not welded to a spacer bar shall be held securely in place by means of wire loops or metal tubes welded to the spacer bar. Suitable ties shall be provided to hold the contraction joint assembly in normal position during shipping, handling and installation. Wire sizes shall be not less than W7 for the outside spacer bars, bearing member and upright supports. The tie wires used for securing the spacer bars shall be not less than W3 wires.

The assembly shall be provided with two continuous bearing plates of not less than 50 mm (2 in.) width and not less than 0.9 mm (0.0359 in.) thickness sheet steel. The bearing plates shall be attached by welding to the subgrade members or by suitable clips and shall be punched to receive the protruding ends of the upright supports and stakes. The stakes shall be driven parallel to and next to the upright supports. The subgrade bearing members may be omitted if suitable subgrade plates are shop welded to the assembly and provide equivalent rigidity. Bearing plates will not be required on stabilized subbases. The welds in the assembly shall be securely made. A broken weld will be sufficient cause for the rejection of the length or section of the assembly in which it occurs.

**1006.12 Steel Forgings.** Steel forgings shall conform to the requirements of AASHTO M 102 and shall be the class specified.

**1006.13 Steel Castings.** Steel castings shall conform to the requirements of AASHTO M 192M (M 192) and shall be of the class specified. When required by the Engineer for the purpose of inspection, castings shall be suspended for tapping and examination of all surfaces.

**1006.14 Gray Iron Castings.** Gray iron castings shall be according to AASHTO M 105 and AASHTO M 306. Castings shall be Class 35. Tensile tests will be required and standard test specimens shall be furnished without charge. The permissible variations of AASHTO M 306 shall be modified as follows:

- (a) Other dimensions + 6mm (1/4 in.).
- (b) Weight (+20 percent drawing/specification weight).

The lid or grate of all castings within the area of the pavement or gutter shall so fit and have contact with the frame as to ensure the lid or grate from jumping or rattling when struck by vehicles.

All frames within the area of the pavement or gutter having circular lids shall have the bearing surfaces of the lid and frame machined or ground so that there will be no variation from a circular, straight edge, of the dimensions corresponding to the lid bearing surface. The diameter of the lid shall be such as to fit the frame without wedging.

Castings for frames, grates and lids shall be proof loaded according to AASHTO M 306. Certification of the test results shall be provided to the Engineer.

**1006.15 Ductile Iron Castings.** Ductile iron castings shall conform to the requirements of ASTM A 536.

Casting for frames, grates and lids shall be fabricated of Grade 65-45-12. Castings lying within the area of the pavement or gutter shall meet the same requirements as specified in Article 1006.14 for gray iron casting.

Casting for frames, grates and lids shall be proof loaded as specified in Article 1006.14.

**1006.16 Malleable Castings.** Malleable castings shall conform to the requirements of ASTM A 47M (A 47), Grade No. 32510.

**1006.17 Steel Rods, Turnbuckles, Bolts, Washers and Other Metal Fastenings for Timber Structures.** Steel rods shall be SAE 1020 or other steel meeting the approval of the Engineer. Turnbuckles shall be drop-forged and conform in dimensions and mass (weight) of the latest Manual of the American Institute of Steel Construction. The distance between the heads shall be 150 mm (6 in.). Bolts shall be U.S. Standard. Lag screws and nails shall be standard form. Washers may be cast, malleable or cut steel.

After fabrication, the rods, turnbuckles, bolts, washers, and other metal fasteners shall be galvanized by the hot-dip process. The zinc coating shall conform to the requirements of AASHTO M 232.

**1006.18 Steel Pipe.** Steel pipe shall be of the size and mass (weight) specified and shall conform to the requirements of ASTM A 53. The pipe shall be black.

**1006.19 Cast Iron Water Pipe.** Cast iron water pipe shall conform to Federal Specifications WW-P-421 for Pipe; Water, Cast-Iron (Bell and Spigot). The pipe shall be of the size and class specified.

**1006.20 Cast Iron Soil Pipe.** Cast iron soil pipe and fittings shall conform to Federal Specifications WW-P-401 for Pipe and Pipe-Fittings; Soil, Cast-Iron. The pipe shall be of the grade known commercially as "Extra Heavy".

**1006.21 Cast Bronze Plates.** Cast bronze for bearing and expansion plates shall conform to the requirements of AASHTO M 107. The bronze shall be Alloy B unless otherwise specified.

**1006.22 Rolled Copper-Alloy Plates.** Rolled copper-alloy for bearing and expansion plates shall conform to the requirements of AASHTO M 108, Alloy 510.

**1006.23 Reserved**

**1006.24 Copper Strip or Sheet.** Copper strip or sheet shall be cold-finished and annealed, soft or 1/8 hard temper, meeting the requirements of AASHTO M 138. The sheet shall stand being bent cold through an angle of 180 degrees flat upon itself without fracture on the outside of the bent portion.

**1006.25 Steel Plate Beam Guardrail.** The bolts and nuts for connections shall be of the design shown on the plans, and shall conform to the requirements of ASTM A 307, Class A. The bolts and nuts shall be galvanized with zinc coating conforming to the requirements of AASHTO M 232 or AASHTO M 298, Class 50. The thickness of the mechanical galvanizing shall not exceed 150  $\mu\text{m}$  (6 mils). Steel plate beam guardrail shall conform to the requirements of AASHTO M 180, Type I, Class A.

In order to prevent rapid oxidation of the zinc coating, the Contractor shall protect all galvanized rail elements, end sections, splice plates, posts and accessories from rain, snow, and other weathering conditions while they are stored on the site prior to installation. This protection shall consist of storing the galvanized parts for the guardrail off the ground surface, so that they will not come in contact with surface run-off water, and properly covering the parts on the top and on all sides. The Contractor shall use special care in storing the rail elements, end sections, and splice plates so that no moisture gets between the pieces when they are stacked in contact with each other.

When erected, the surfaces of the rail elements, end sections, and splice plates shall have a bright finish and shall not be tarnished. If "white rust" (zinc oxide) has formed on any of the surfaces of the rail elements, end sections, and splice plates, the affected material will be rejected by the Engineer.

**1006.26 Cables, Springs, Accessories, Offset Brackets, and Spring Expansion Take-ups for Cable Road Guard.**

- (a) Cables and Fastenings. Wire cable and fastenings for cable road guard shall conform to the requirements of AASHTO M 30, Class A Wire Rope.
- (b) Springs. All springs shall be made from spring steel conforming to the requirements of ASTM A 689, except that the silicon requirements may be waived.
- (c) Rods, Turnbuckles, Bolts and Washers. The steel used in the manufacture of the rods shall comply with the requirements of the latest revision of SAE 1020 or other steel meeting the approval of the Engineer. Turnbuckles shall be drop-forged and conform in dimensions to the latest Manual of the American Institute of Steel Construction. Bolts shall be U.S. Standard. Lag

screws and nails shall be standard form. Washers may be cast, malleable, or cut steel.

After fabrication, the springs, rods, turnbuckles, bolts and washers shall be galvanized according to the requirements of AASHTO M 232. The small articles may be zinc-coated by the mechanically deposited process conforming to AASHTO M 298, Class 50. The thickness of the mechanical galvanizing shall not exceed 150  $\mu\text{m}$  (6 mils).

- (d) Offset Brackets. The type and design of brackets will be limited to those which have been approved by the Engineer and for which approved plans and Specifications are on file with the Department. The brackets shall be one of the following types:
  - (1) Offset Spring Brackets. The offset spring brackets shall have a deflection of 25 mm (1 in.) under a compression load of not less than 15.5 kN (3500 lb) and not more than 26 kN (6000 lb) applied for one minute perpendicular to the line of the cables with the cables in place. Upon release of the load, the brackets shall show a permanent set or deformation of not more than 10 mm (3/8 in.). The permanent set or deformation shall be measured between the points of attachment of the bracket and the cable and the base of the bracket. The offset spring brackets shall not collapse under a compression load of 45 kN (10,000 lb).
  - (2) Special Offset Spring Brackets. Special offset spring brackets of the blunt, slotted, overlapping nose type shall be fabricated from spring steel tempered and drawn. The brackets with steel stay pins shall be slotted for three cables. Special offset spring brackets shall have a minimum deflection of 25 mm (1 in.) under a compression load of 67 kN (15,000 lb) applied for one minute perpendicular to the line of the cables at the points of attachment of the cables and the bracket with the cables in all slots. Upon release of the load, the bracket shall show a permanent set or deformation of not more than 13 mm (1/2 in.), measured on the outside limits of the bracket from front to back. A manufacturing tolerance of  $\pm 3$  mm (1/8 in.) will be allowed in the height and width of the special offset spring bracket.
- (e) Spring Expansion Take-ups. The end spring expansion take-ups shall consist of one coil spring, one cable end fitting for 19 mm (3/4 in.) wire cable and 19 mm (3/4 in.) rods and nuts. It shall be designed for attachment to the end or anchor posts. The spring shall be of sufficient strength to provide a 125 mm (5 in.) take-up in a 19 mm (3/4 in.) wire cable 150 m (500 ft) long.

#### **1006.27 Chain Link Fence.**

- (a) Fabric. The fabric shall be according to one of the following:
  - (1) The fabric shall be woven in 50 mm (2 in.) mesh with 3.75 mm (0.148 in.) diameter wire meeting one of the following requirements of AASHTO M 181:

- a. Type I, Class D (zinc-coated steel)
  - b. Type II (aluminum-coated steel)
  - c. Type III (aluminum alloy)
  - d. Type IV, Class B (polyvinyl chloride (PVC)-coated steel). When vinyl-coated fabric is used, the posts, fence framework, gates, tension wire, fabric ties, and fittings shall be vinyl-coated according to the same requirements as the coating of the fabric. All nonaluminum material shall be galvanized prior to vinyl coating.
- (2) Fabric shall be according to ASTM F 1345, woven in 50 mm (2 in.) mesh with 3.75 mm (0.148 in.) diameter wireprotected by Class 2 mischmetal coating. The weight of Zn - 5A1 - MM alloy coating shall not be less than 305 g/sq m (1.0 oz/ sq ft) of uncoated wire surface.
- (b) Metal Posts. Metal posts, rail, braces, and gate frames shall be the shape and dimension as shown on the plans and shall meet the bending strength and dimension tolerance of AASHTO M 181.
- Pipe and rolled shapes shall conform to ASTM F 669, Table 2. Metallic coating shall conform to ASTM F 1234, Table 2. Square hollow structural steel tubing shall conform to ASTM A 500 Grade B or ASTM A 501, with ASTM F 1234, Type A internal and external coating.
- (c) Tension Wire. Tension wire shall conform to the requirements of AASHTO M 181, Type I, Class 2, or Type II.
- (d) Fabric Ties. The fabric ties to be used with other than vinyl-coated fabric shall be stainless steel hog rings (minimum diameter [3 mm (0.120 in.)], 9 gage aluminum wire or 9 gage galvanized steel wire with 370 g/sq m (1.2 oz/sq ft) zinc coating. The fabric ties to be used with vinyl fabric shall be of the same material as the fabric.
- (e) Fittings. All miscellaneous fittings shall be made of malleable cast iron or pressed steel and shall be galvanized according to AASHTO M 232.
- (f) Bolts and Nuts. All bolts and nuts shall conform to the requirements of ASTM A 307 and shall be zinc-coated according to AASHTO M 232 or AASHTO M 298, Class 50 with galvanizing not to exceed 150  $\mu$ m (6 mils).

#### **1006.28 Woven Wire Fence.**

- (a) Woven Wire Fencing. Woven wire fencing may be either galvanized steel wire fencing or aluminum-coated steel wire fencing. Galvanized steel wire fencing shall conform to the requirements of AASHTO M 279, Class 3, Design Number 939-6-11. Aluminum-coated steel wire fencing shall conform to the requirements of ASTM A 584, Design Number 939-6-11.

- (b) **Barbed Wire.** Barbed wire may be either galvanized steel barbed wire or aluminum-coated steel barbed wire consisting of two strands of 12 1/2 gage wire with four point barbs of 14 gage wire spaced 125 mm (5 in.) apart. Galvanized barbed wire shall conform to the Specifications for zinc-coated (galvanized) steel barbed wire, AASHTO M 280, Class 3 with a minimum coating of 245 g/sq m (0.80 oz/sq ft) of wire surface. Aluminum-coated steel barbed wire shall conform to the Specifications for galvanized steel barbed wire, except the wire shall be aluminum coated. The wire shall have not less than 76 g (0.25 oz) coating of aluminum alloy per square meter (square foot) of uncoated surface. The weight of the aluminum alloy coating shall be determined according to AASHTO T 213.
- (c) **Brace Wires.** Brace wires shall be galvanized or aluminum alloy coated No. 9 gage steel wire conforming to the Specifications for galvanized steel or aluminum alloy coated fencing.
- (d) **Metal Posts.** Metal posts shall be the shapes and dimensions shown on the plans. Line posts shall include a firmly attached, tapered anchor plate having an area of not less than 12000 sq mm (18 sq in.). The anchor plate shall be fabricated from not less than 12 gage thickness steel. Steel pipe for metal posts shall be steel pipe, Type A, Type B, or Type C according to Article 1006.27. Structural shapes for posts shall be fabricated from steel conforming to the requirements of AASHTO M 281, Grades A or B. All structural shapes shall be galvanized according to AASHTO M 111 using zinc of any grade conforming to the requirements of AASHTO M 120. The zinc coating shall be not less than 610 g/sq m (2.0 oz/sq ft) of surface.

Square hollow structural tubing shall conform to the requirements of ASTM A 500, Grade B or ASTM A 501. The tubing shall be galvanized inside and outside according to AASHTO M 111, using zinc of any grade conforming to the requirements of AASHTO M 120. The coating shall be not less than 610 g/sq m (2.0 oz/ sq ft) of surface.
- (e) **Metal Braces.** Metal braces shall have the shapes and dimensions shown on the plans. They shall conform to the Specifications for metal posts, either steel pipe or structural shapes, and shall be galvanized as specified for the metal posts.
- (f) **Gate Frames.** Gate frames shall consist of galvanized steel pipe having the dimensions shown on the plans and conforming to the specifications for steel pipe line posts.
- (g) **Miscellaneous Materials.** Miscellaneous materials such as, but not limited to, wire, clips, or other metal devices for fastening the barbed wire and fencing to the posts, shall be of good commercial quality and galvanized. Staples shall be at least 38 mm (1 1/2 in.) long of No. 9 galvanized wire.
- (h) **Post Tops.** Steel pipe and steel tubing posts shall be furnished with steel or malleable iron or wrought iron post tops of approved type, and shall be galvanized according to AASHTO M 232.

**1006.29 Metal Posts and Hardware for Highway Markers, Signs and Delineators.** Metal posts for highway markers, signs and delineators shall conform to the following requirements except that delineator posts shall be unfinished steel.

(a) Post Materials.

- (1) Steel. The steel used in the posts shall be hot rolled conforming to the physical properties of ASTM A 499, Grade 60 and to the chemical properties of ASTM A 1 for 41 kg (91 lb) or for larger steel rails.
- (2) Aluminum. The aluminum used in the posts shall conform to the requirements of ASTM B 221M (B 221), Alloy 6061-T6, which shall meet the following minimum requirements:

Tensile strength .....260,000 kPa (38,000 psi)  
Yield point .....240,000 kPa (35,000 psi)  
Elongation 50 mm (2 in.) ..... 10 percent

(b) Fabrication and Finish:

- (1) Mass (Weight). The average mass (weight) of the posts per meter (foot) of length shall be not less than the following:

Type of Post	Kilograms per Meter (lb/ft)	
	Aluminum	Steel
A	1.3 (0.90)	3.0 (2.00)
B	1.9 (1.30)	4.5 (3.00)
C	---	1.7 (1.12)

Individual posts shall not vary more than ten percent below their average weight.

- (2) Punching. In the case of steel posts, all punching or drilling shall be done prior to galvanizing.
- (3) Galvanized Steel Posts. Steel posts shall be galvanized by the hot-dip process according to AASHTO M 111.
- (4) Enameled Steel Posts. Steel posts shall be painted with a weather resistant, rust inhibitive, high quality, dark green enamel which shall produce a hard mar resistant coating, free from paint cracks, blisters, or other defects. The quality of the paint shall be such that when the finished post is struck a light blow with a sharp tool, the paint shall not crack or chip, and if scratched with a knife, shall not powder. The thickness of the dry film enamel shall be a minimum of 25 µm (1 mil.). It



shall pass the standard 100 hour salt spray test [20 percent solution by spray of fog 21 °C (70 °F)]. Painting shall be the final process after all thickness of the dry film enamel shall be a minimum of 25 µm (1 mil.). It shall pass the standard 100 hour salt spray test [20 percent solution by spray of fog 21 °C (70 °F)]. Painting shall be the final process after all fabrication and punching has been completed.

The enamel for steel posts shall have the following properties:

Solids by Mass (Minimum) .....	54.6%
Mass kg/L (lb/gal) (Minimum) .....	1 (8.6)
Viscosity at 25 °C (77 °F) .....	45-50 sec.
	No. 4 Ford
60% Gloss .....	High
Method of Application .....	Flow Coat
Cure Schedule 150 °C (300 °F) .....	20 minutes

- (5) Polyester Coated Steel Posts. Steel posts shall be coated with an electrostatically applied powder coating of a dark green, pigmented, urethane-cured, polyester having the following properties:

Polyester Resin (Molecular weight equivalent 2,000-5,000) .....	40-75%
Blocked Isocyanate Curing Agent (Molecular weight equivalent 1,000-3,000) .....	10-25%
Flow Control Agent (Acrylo-terpolymers) .....	0.1-2.0%
Exterior Durable Grade Pigment and Extender .....	25-50%
Organic Volatile Content (Maximum) .....	3%

The posts shall be cleaned free of oil, loose mill scale and rust by pickling or by blast cleaning to near white with a blast profile not greater than 50 µm (2 mils.). They shall then be pretreated with 430 to 750 mg/sq m (40 to 70 mg/sq ft) of iron phosphate and chemically sealed.

The coating shall be applied immediately after cleaning as an electrostatically charged dry powder sprayed onto the grounded post using an electrostatic spray gun. The thickness of the applied coating shall be a minimum of 63 µm (2.5 mils) measured on a flat surface of the post according to ASTM D 1186.

All systems for handling the coated posts shall have padded contact areas. All bundling bands shall be padded or suitable banding shall be used to prevent damage to the coating. The posts or bundles shall not be dropped or dragged. The bundled posts shall be transported with care and stored above the ground on wooden or padded supports.

- (6) Workmanship and Finish. The posts shall be symmetrical and well formed. They shall be free from injurious defects which will impair their strength or appearance. The zinc coating on the steel posts shall be free from such imperfections as lumps, blisters, uncoated spots, dross, and flux.

## (c) Tests.

- (1) Tension Tests. The tensile properties of the metals shall be determined by the method outlined in AASHTO T 68.
- (2) Tests for Weight of Zinc Coating. The weight of the zinc coating shall be determined by the method outlined in AASHTO M 111. As an option, the weight of the coating may be determined by weighing one or more full size specimens after pickling and drying and again after coating.
- (3) Tests for Polyester Coating. The coated posts shall be capable of meeting the following requirements:

Impact. The coating shall show no cracks or breaks when subjected to an impact of 11 J (100 in. lb) according to ASTM D 2794.

Salt Spray. When tested for 500 hours according to ASTM B 117, no rust, blisters or undercutting of uncoated or scribed areas will be apparent.

Humidity. There shall be no blistering of the coating or gloss loss greater than five percent when tested according to ASTM D 2247.

Weathering. There shall be no more than 15 percent loss of gloss and no appreciable color change when tested for 1,000 hours in a carbon arc weatherometer according to ASTM G 23, Type EH.

- (4) Certification. When steel posts are supplied, the Contractor shall furnish a certification from the manufacturer that the posts meet the specified chemical and physical properties. The Department reserves the right to test samples for these and other requirements of these Specifications.
- (d) Hardware. Hardware for attaching sign panels to posts and other applications shall be zinc coated steel or stainless steel.

Steel bolts, nuts, and washers shall conform to the requirements of ASTM A 307. They shall be zinc-coated according to the requirement of AASHTO M 232, AASHTO M 298, Class 50, or ASTM B 633M (B 633) SC 3.

Stainless steel bolts shall conform to the requirements of ASTM A 193M (A 193), Class 1, Grade B 8M or B8. Stainless steel nuts shall conform to the requirements of AASHTO M 292, Grade 8 or 8F, and the washers shall conform to ASTM A 240, Type 302 or 304.

**1006.30 Aluminum for Railings.**

- (a) Cast Aluminum Railing Posts. Cast aluminum railing posts shall conform to the requirements of AASHTO M 193, Alloy A 444-T4.

- (b) Aluminum Alloy Extruded Rail. Aluminum alloy extruded rail shall conform to the requirements of ASTM B 221M (B 221), Alloy 6061-T6 or 6351-T5 with a minimum yield of 240,000 kPa (35,000 psi), a minimum tensile strength of 260,000 kPa (38,000 psi), and an elongation of ten percent in 50 mm (2 in.).

#### **1006.31 Stainless Steel Hardware.**

- (a) Stainless Steel Machine Bolts or Cap Screws. Stainless steel nuts, washers, lock washers, machine bolts or cap screws shall conform to the requirements of Article 1006.29(d).
- (b) Stainless Steel Bars. Stainless steel bars shall conform to the requirements of ASTM A 276, Type No. 302 or 304, Condition B. Threads, when required, shall be Class 2B.

**1006.32 Stud Shear Connectors.** Stud shear connectors shall conform to the requirements of AASHTO M 169 cold drawn bars, Grades 1015, 1018 or 1020, either semi- or fully-killed. Welding and workmanship shall be according to the requirements of the BWC.

**1006.33 Seamless Copper Water Tube.** Seamless copper water tube shall conform to the requirements of ASTM B 88M (B 88), Type K, except that the tolerance for wall thickness and mass/meter (weight/foot) shall be increased by 50 percent.

#### **1006.34 Galvanized Steel for Railings.**

- (a) Steel Posts for Railings. Steel posts shall conform to the requirements of AASHTO M 270, Grade 50, and shall be galvanized according to AASHTO M 111.
- (b) Tubular Steel Rail for Railings. Tubular steel rail shall conform to the requirements of ASTM A 500, Grade B, and shall be galvanized according to AASHTO M 111.

Tubular steel from all heats supplied shall be tested for impact toughness according to AASHTO T 266, "Charpy V-Notch (CVN) Impact Testing of Metallic Materials". The CVN impact requirements shall be 20 J (15 ft lb) at -18 °C (0 °F). For each heat supplied, the manufacturer shall furnish one 50 x 450 mm (2 x 18 in.) specimen, marked with its heat number, for impact testing.

In lieu of the above, the manufacturer may choose to supply tubing that has been tested for toughness according to ASTM E 436, "Standard Method for Drop-Weight Tear Tests of Ferritic Steels", as modified herein. Tubing test samples shall be taken and tested prior to delivery of the railing to the Contractor. The taking of the test samples shall be witnessed, and the testing shall be performed, by an approved independent testing laboratory.

Drop-weight tear testing shall be done on test specimens obtained from galvanized tubing with the same heat number as that being used. Testing

shall be conducted at a temperature of  $-18^{\circ}\text{C}$  on 50 x 225 mm (0 °F on 2 in. x 9 in.) specimens supported to provide a 175 mm (7 in.) clear span. Galvanizing shall not be removed from the specimens. Three 50 x 225 mm (2 in. x 9 in.) test specimens shall be cut from each of the unwelded sides for a total of nine specimens.

The three specimens from the side with the lowest average shear area shall be disregarded when calculating the final average shear area. The final average shear area shall then be calculated using the six remaining specimens. If the average shear area falls below 50 percent, material from the heat represented by these tests shall be rejected, except that if the average shear area is 30 percent or greater, one retest at a sampling frequency three times that of the first test, and with no samples excluded in calculating the average, will be permitted. Material not having a 50 percent average shear area upon retest shall be rejected. Certified test data shall be submitted with each shipment of railing.

No transverse welds will be permitted in the rail section.

The manufacturer of the tubing shall, before galvanizing, identify the product with the steel heat number (or with some number that is traceable to the heat number) and a unique manufacturer's identification code. The identification method shall be such that identification shall be on only one face of the section, be repeated at intervals no greater than 1.2 m (4 ft), and not extend into the curved surface of the tubing at the corners.

- (c) Steel Shapes and Plates for Railing. Steel angles shall conform to the requirements of AASHTO M 270M, Grade 345 (M 270, Grade 50), and all other steel shapes and plates shall conform to the requirements of AASHTO M 270M, Grade 250 (M 270 Grade 36). This material shall be galvanized according to AASHTO M 111.
- (d) Storing on Site. In order to prevent rapid oxidation of the zinc coating, the Contractor shall protect all galvanized rail elements, splice sections, posts, and accessories from rain, snow, and other weathering conditions while they are stored on the site prior to installation. This protection shall consist of storing the galvanized parts of the railing off the ground surface so that they will not come in contact with surface run-off water and of properly covering the parts on the top and all sides. The Contractor shall use special care in storing this material so that no moisture gets between the pieces when they are stacked in contact with each other. When erected, the surfaces of the rail elements and posts shall have a uniform finish and shall not be tarnished, have mottled areas or a gritty appearance, nor show dip marks or brush marks. If "white rust" (zinc oxide) has formed on any of the surfaces of the rail elements, the affected material shall be rejected by the Engineer.

**1006.35 Gabions and Slope Mattresses.** The material shall conform to the following requirements:

- (a) Fabric. The baskets shall be constructed of galvanized, aluminized, or PVC-coated galvanized or aluminized steel wire.

- (1) Gabion baskets shall be constructed of one of the following two types:
- Hexagonal mesh fabric with at least three half twists. The fabric opening shall have nominal dimensions of 82 mm x 115 mm (3.25 in. x 4.50 in.).
  - Welded wire fabric with a minimum average weld shear value of 2600 N (584 lb) with no value less than 2000 N (450 lb). The fabric opening shall have nominal dimensions of 76 mm x 76 mm (3.00 in. x 3.00 in.).
- (2) Slope mattress baskets shall be constructed of one of the following two types:
- Hexagonal mesh fabric with at least three half twists. The fabric opening shall have nominal dimensions of 60 mm x 82 mm (2.50 in. x 3.25 in.).
  - Welded wire fabric with a minimum average weld shear value of 1300 N (290 lb) with no value less than 1000 N (225 lb). The fabric opening shall have nominal dimensions of 38 mm x 76 mm (1.50 in. x 3.00 in.).
- (b) Wires for Selvedges, Lacing, and Internal Connections. All wires shall be of the same material and coating finish as the fabric.
- (c) Galvanized Steel Wire. The wire shall conform to the requirements of ASTM A 641M (A 641), Class 3, Soft.
- (d) Aluminized Steel Wire. The wire shall conform to the requirements of ASTM A 809, Soft.
- (e) PVC-Coated Galvanized or Aluminized Steel Wire. The PVC coating shall be applied to wire conforming to ASTM A 641M (A 641), Class 3, Soft, or ASTM A 809, Soft. The PVC shall be extruded and adhered (bonded), shall conform to the requirements of ASTM D 2287 and shall be 0.500 mm ( $\pm 0.127$  mm) [0.020 in. ( $\pm 0.005$  in.)]. The color of the PVC material shall be gray. The PVC coating shall be self-extinguishing and shall not support combustion when subject to the horizontal flame test of ASTM A 470.
- (f) Wire Diameter. The minimum diameter of wires after coating for gabions and slope mattresses shall be according to the following tables:

	GABIONS Aluminized and Galvanized	PVC
Fabric Wire	3.0 mm (0.118 in.)	3.5 mm (0.136 in.)
Selvedge Wire <sup>1/</sup>	3.8 mm (0.150 in.)	4.1 mm (0.163 in.)
Lacing and Internal Connecting Wires	2.2 mm (0.087 in.)	3.0 mm (0.117 in.)

SLOPE MATTRESSES		
	Aluminized and Galvanized	PVC
Fabric Wire	2.2 mm (0.087 in.)	3.0 mm (0.117 in.)
Selvedge Wire <sup>1/</sup>	2.7 mm (0.106 in.)	3.5 mm (0.136 in.)
Lacing and Internal Connecting Wires	2.2 mm (0.087 in.)	3.0 mm (0.117 in.)

1/ Does not apply to welded wire fabric.

**1006.36 Wire Fasteners.** Wire fasteners shall be made of galvanized steel wire, aluminized steel wire or stainless steel wire. Galvanized wire fasteners shall be used on galvanized baskets, aluminized wire fasteners shall be used on aluminized baskets, and stainless steel wire fasteners shall be used on PVC coated baskets. Wire fasteners shall resist a force of at least 2700 N (600 lb) while remaining in a closed position when subjected to a directional tension force along any axis of the fastener.

- (a) Galvanized Steel Wire. Coating requirements shall conform to ASTM A 764, Type 3.
- (b) Aluminized Steel Wire. Coating requirements shall conform to ASTM A 809.
- (c) Stainless Steel Wire. The wire shall conform to ASTM A 313, 302 grade.

**1006.37 Reserved.**

**SECTION 1007. TIMBER AND PRESERVATIVE TREATMENT**

**1007.01 Description.** This Specification covers structural timber for bridges and guardrail, timber piling, guard and guide posts, bracing stakes, woven wire fence posts and braces, and preservative treatment.

Inspection of both treated and untreated products except untreated native timber piling and the preservatives shall be performed by an independent agency engaged by the Contractor directly or through his/her supplier and approved by the Engineer. The cost of this inspection shall be included in the unit bid price. Acceptance for incorporation into a project will be based on an inspection report by an approved agency, showing compliance with the Specifications, and satisfactory results or any random inspection performed at the supplier's yard or the project site. Untreated native timber piling will be inspected at the source or at its destination by the Engineer.

**1007.02 Definition of Terms.** The terms used shall be interpreted according to ASTM D 9.

**1007.03 Structural Timber.** Only southern pine and Douglas fir (coast region) will be admitted for use as structural timber.

- (a) **Treated and Untreated Timber.** When treated material is specified, the method of treatment shall be according to Article 1007.12. There shall be no heartwood requirements for timber which is to receive a preservative treatment and the amount of sapwood shall not be limited. All timber to be used without preservative treatment shall contain not less than 85 percent of heartwood measured on the girth.
- (b) **Standard Sizes and Grading Requirements.** Rough cut and surfaced timber shall meet the applicable requirements for size and grading according to ASTM D 245 and the Southern Pine Inspection Bureau, or the West Coast Lumber Inspection Bureau except as provided herein.

All pieces shall be cut to length with square ends.

**1007.04 Bridges.** Floor planks shall conform to the requirements provided for 1850 F dense southern pine or 1900 F dense Douglas fir. All other timber for bridges, except floor planks, shall conform to the requirements for 1600 F dense southern pine or 1700 F dense Douglas fir. The dimensions and surfacing requirements for all bridge timber will be shown in the contract.

**1007.05 Wood Guardrail.** The posts, rails and other timber for wood guardrail shall comply with the requirements for No. 1 Dense SR 1550 F for southern pine or No. 1 Dense 1400 F for Douglas fir. The size and surfacing requirements for the timber will be shown in the contract.

**1007.06 Steel Plate Beam Guardrail.** The posts and other timber for steel plate beam guardrail shall comply with the requirements for No. 1 Dense SR 1550 F for southern pine or No. 1 Dense 1400 F for Douglas fir. The size and surfacing requirements will be shown in the contract.

**1007.07 Cable Road Guard.** The posts and other timber for cable road guard shall comply with requirements for No. 1 Dense SR 1550 F for southern pine or No. 1 Dense 1400 F for Douglas fir. The size and surfacing requirements will be shown in the contract.

**1007.08 Piling.** Timber piling shall be treated or untreated.

- (a) **Untreated Timber Piling.** When untreated timber piles are specified, they shall be any of the following species of woods which will satisfactorily withstand driving:

Cedar, Northern White	Pine, Southern
Cedar, Western Red	Pine, Norway
Chestnut	Cypress
Elm, Rock	Fir, Douglas (coast region)
Hickory	Oak

- (b) Creosoted Timber Piling. When creosoted timber piles are specified, they shall be:

Pine, Southern  
Fir, Douglas (coast region)  
Oak, Red (commercial)

The method of treatment shall be according to Article 1007.12.

- (c) Quality. All timber piles shall be cut from sound and solid trees. To avoid deterioration, they shall be cut within 12 months prior to use. The butt and tip shall be cut square with the axis of the pile. Piles shall be cut above the ground swell and shall taper from butt to tip. All knots and limbs shall be trimmed or cut flush with the surface of the pile.

The piles shall contain no unsound knots or knots in groups. Sound knots will be permitted provided the diameter of the knot does not exceed 100 mm (4 in.) or 1/3 of the diameter of the pile at the point where it occurs. The piles shall be free from twist of grain exceeding 1/2 the circumference in any 6 m (20 ft.) of length; shake more than 1/3 the diameter of the pile, or shake appearing on both ends of the pile; rot, incipient, or advanced decay; and season checks which penetrate more than 1/4 of the diameter of the pile or are more than 6 mm (1/4 in.) in width. Any defect or combination of defects, which will impair the strength of the pile more than the maximum knot, will not be permitted.

Untreated piles shall have all the outer bark removed. Piles to be treated shall be peeled by removing all the outer bark and at least 80 percent of the inner bark. No strip of inner bark remaining on the piles shall be over 20 mm (3/4 in.) wide and there shall be at least 25 mm (1 in.) of clean wood surface between any two such strips.

A line drawn from the center of the tip to the center of the butt shall not fall outside the center of the pile at any point more than one percent of the length of the pile. In short bends, the distance from the center of the pile to a line stretched from the center of the pile above the bend to the center of the pile below the bend shall not exceed 4 percent of the length of the bend, or 65 mm (2 1/2 in.). Piles shall be free from reverse bends.

- (d) Dimensions. All measurements shall be made under the bark. Tip and butt measurements shall be as listed in the following table:

Length of Pile	DIAMETER - (mm)		
	Tip Minimum	900 mm From Butt Minimum	Butt Maximum
Less than 6 m	200	275	500
6 m and less than 12 m	200	300	500
12 m and less than 18 m	175	325	500
18 m and more	150	325	500



Length of Pile	DIAMETER - (in.)		
	Tip Minimum	3 ft From Butt Minimum	Butt Maximum
Less than 20 ft	8	11	20
20 and less than 40 ft	8	12	20
40 and less than 60 ft	7	13	20
60 ft and more	6	13	20

**1007.09 Guard Posts and Guide Posts.** The posts shall be of southern pine, Douglas fir, northern white cedar, redwood, green and white ash, American and slippery elm, black gum, or red oak.

- (a) Dimensions. The dimensions of the posts will be shown in the contract.
- (b) Quality. The posts shall be cut from sound and solid trees. They shall contain no unsound knots. Sound knots will be permitted, provided the diameter of the knot does not exceed  $\frac{1}{3}$  the diameter of the post at the point where it occurs. They shall be free from excess twist of grain; ring shake more than  $\frac{1}{3}$  the diameter of the post; and rot, incipient or advanced decay, except that in northern white cedar one pipe rot in the top of the post, and butt rot not to exceed five percent of the area of the butt will be permitted. Season checks which penetrate more than  $\frac{1}{4}$  the diameter of the posts at the point measured or which are more than 6 mm ( $\frac{1}{4}$  in.) in width will not be permitted. The post shall be free from short or reverse bends. One way sweep or crook will be permitted provided it does not exceed 50 mm (2 in.) measured at its maximum deviation.

**1007.10 Bracing Stakes.** Stakes for bracing trees and shrubs shall be of any species of wood which are durable and of sufficient strength to satisfactorily withstand driving.

- (a) Dimensions. For round stakes, the tip diameter shall be not less than 45 mm ( $1\frac{3}{4}$  in.) nor more than 63 mm ( $2\frac{1}{2}$  in.), and the butt diameter shall not exceed 75 mm (3 in.). Sawed stakes shall be not less than 45 mm ( $1\frac{3}{4}$  in.) nor more than 50 mm (2 in.) in width and thickness. The stakes shall be 2.5 m (8 ft.) in length; a variation of 50 mm (2 in.) will be permitted.
- (b) Quality. The stakes shall be cut from sound timber. They shall contain no decayed knots, except that small pith knots will be permitted. The diameter of sound knots shall not exceed  $\frac{1}{2}$  the diameter of the stake at the point where they occur. They shall be free from excess twist of grain; excessive ring shake; and rot, except that in round stakes, pipe rot in the tip of the stakes which does not exceed 15 mm ( $\frac{1}{2}$  in.) in diameter, and butt rot which does not exceed five percent of the area of the butt will be permitted. Season checks shall not penetrate more than  $\frac{1}{4}$  the diameter of the stake. The stakes shall be free from short or reverse bends. One way sweep or crook will be permitted provided it does not exceed 75 mm (3 in.) measured at its maximum deviation. No more than ten percent of the number of stakes in any lot shall contain the maximum crook or butt rot. The stakes shall be peeled of all outer bark, and all knots and branches shall be cut flush with

the surface. The stakes shall be sharpened for driving and the opposite ends cut square.

**1007.11 Woven Wire Fence Posts and Braces.** The posts and braces shall be of southern yellow pine or Douglas fir.

- (a) Dimensions. The dimensions of the posts and braces will be as shown in the contract. They may be either round or rectangular and if rectangular, they may be rough sawn or surfaced to standard dimensions.
- (b) Quality. The posts and braces shall have all the bark removed, knots and projections trimmed flush with the surface, shall be sound and free from decay, excessive twists of grain, unsound knots or knots in groups, or any structural defects. Knots in the posts shall not exceed 40 mm (1 1/2 in.) in size.

**1007.12 Preservative Treatment.** All products except piling may be inspected prior to treatment at the option of the Engineer. Timber piling shall be inspected prior to treatment and after for preservative retention. All products shall be inspected after treatment for any deviation from the requirements of the Specifications caused by the treating process.

- (a) Preservatives. The preservatives permitted shall be one of the following:
  - (1) Creosote Oil. Creosote oil shall conform to the requirements of AWPA Standard P1.
  - (2) Pentachlorophenol. Pentachlorophenol shall be a mixture of not less than five percent pentachlorophenol and petroleum solvent. Pentachloro-phenol shall conform to the requirements of AWPA Standard P8. Petroleum solvent shall be Type A and conform to the requirements of AWPA Standard P9.
  - (3) Water-Borne Preservative. Ammoniacal copper arsenate (ACA) shall conform to the requirements of AWPA Standard P5. Chromated copper arsenate (CCA) shall meet the requirements of AWPA Standard P5, Type A, Type B, or Type C.
- (b) Conditioning for Treatment. All timber products shall be seasoned before treatment as described in AWPA Standard C1. Since difficulty may be encountered in obtaining the specified retention and penetration, it is the responsibility of the treater to select timber for treatment that has sufficient sapwood thickness to permit penetration and retention as specified.

Suitable conditioning and, for some species, incising prior to treatment, and the use of treating conditions that do not damage the wood according to AWPA Standard C1 and the AWPA Commodity Standards listed below are additional responsibilities of the treater.
- (c) Treating Process. Treatment with creosote oil or pentachlorophenol solution shall be by one of the empty-cell processes. Treatment with water-borne preservatives shall be by the full-cell process.

- (d) Special Treatment for Timber and Posts. Timber for wood guardrail, steel beam guardrail, cable road guard, guard posts, and guideposts which have been given oil preservative treatment, before being removed from the cylinder, shall be further subjected to live steam at a maximum pressure of 90 N (20 lb) and, following that, to an additional period of vacuum to ensure that the surface of the wood is free of accumulation of oil and tarry material.
- (e) Retention of Preservative. Retentions and preservatives permitted shall be according to AWP Standard C1 and the AWP Commodity Standards listed in the following table.

Preservative Retention Requirements kg per m <sup>3</sup>					
Product and Usage	Creosote	Penta-Chlorophenol	ACA	CCA	AWPA Standard
Piles:					
Southern Pine	192.2	9.6	12.8	12.8	C3
Coastal Douglas Fir	272.3	13.6	16.0	16.0	C3
Oak	96.1	4.8	NA*	NA*	C3
Posts:					
Guard, Guide, Sign, Fence and Braces					
Round	128.2	6.4	6.4	6.4	C14
Sawn Four Sides	160.2	8.0	8.0	8.0	C14
Guardrail and Spacer Blocks					
Round	160.2	8.0	8.0	8.0	C14
Sawn Four Sides	192.2	9.6	9.6	9.6	C14
Lumber:					
For Bridges and Retaining Walls	192.2	9.6	9.6	9.6	C14
For Wood Guardrail	128.2	6.4	3.7	3.7	C14
Miscellaneous Lumber for Human Contact: (Handrails, Picnic Tables, Etc.)					
In Contact with Ground or Water	NA*	NA*	6.4	6.4	C2
Not in Contact with Ground or Water	NA*	NA*	4.0	4.0	C2

\*Not allowed

Preservative Retention Requirements Pounds Per Cubic Foot ENGLISH					
Product and Usage	Creosote	Penta- Chlorophenol	ACA	CCA	AWPA Standard
Piles:					
Southern Pine	12.0	0.60	0.80	0.80	C3
Coastal Douglas Fir	17.0	0.85	1.00	1.00	C3
Oak	6.0	0.30	NA*	NA*	C3
Posts:					
Guard, Guide, Sign, Fence and Braces					
Round	8.0	0.40	0.40	0.40	C14
Sawn Four Sides	10.0	0.50	0.50	0.50	C14
Guardrail and Spacer Blocks					
Round	10.0	0.50	0.50	0.50	C14
Sawn Four Sides	12.0	0.60	0.60	0.60	C14
Lumber:					
For Bridges and Retaining Walls	12.0	0.60	0.60	0.60	C14
For Wood Guardrail	8.0	0.40	0.23	0.23	C14
Miscellaneous Lumber for Human Contact: (Handrails, Picnic Tables, Etc.)					
In Contact with Ground or Water	NA*	NA*	0.40	0.40	C2
Not in Contact with Ground or Water	NA*	NA*	0.25	0.25	C2

\*Not allowed

- (f) Handling and Storage. Handling and storage of lumber items shall be as specified in AWPAs Standard M4.

Treated material shall be placed in a position as to facilitate thorough drainage of any preservative remaining on the material. AWPAs Standard M4 shall be used for repair of cuts and abrasions and treatment of bored holes. Three brush coats of the repair material shall be used. Each coat shall be allowed to dry before the next coat is applied. Treated material which is otherwise satisfactory may be rejected if coated with dirt. When material is stored for an extended length of time, the material shall be protected from the weather.

- (g) Product Marking. Treated material shall be either hammer or heat-branded, dye-stamped, or metal-tagged according to AWPAs Standard M1 and M6, except that branding of piles shall be on the butt end. The charge number shall be included in the markings on all treated piles. Sawn materials 50 mm (2 in.) or less in nominal thickness that is treated with oil-type preservative

may be bundled with tags being attached to the bundles. In lieu of bundle tags, when such materials are treated with water-borne preservative, the required information may be dye-stamped on the outer pieces of the bundle.

- (h) Inspection. All treated material shall be inspected according to AWWA Standard M2 . Penetration and retention shall be determined by the assay method. Test reports listing test results shall accompany each shipment of treated material. The Department, at its option, may require a random check on preservative retention.

## **SECTION 1008. PAINT MATERIALS AND MIXED PAINTS**

**1008.01 General.** All paint materials for use in the manufacture of these paints shall be delivered in the original packages and shall be used without adulteration. With the exception of aluminum paint, the paints shall be made by thoroughly dispersing the pigments in a portion of the vehicle and thinning with the remainder of the vehicle. The pigments shall be dispersed with an approved roller mill, pebble mill, ball mill or a high speed dispersion mill using a carborundum rotor and stator in such a manner that very little heat is developed. The dispersion of all pigments in the paints shall be such that the coarse particles and skins (total residue retained on a 45 µm (No. 325) sieve, based on pigment) will not exceed 1.5 percent. The quantities of paint materials and the quantities of pigment and vehicle used in formulating a paint shall be based on the average percentage of the minimum and maximum composition limits given in the Specifications. The manufacturer shall furnish to the Department the batch formula which will be used in manufacturing the paint. Paints shall be produced which during storage will not thicken, "skin over", liver, settle out appreciably, or cake badly in the containers, and which can be readily broken up with a paddle to a smooth, uniform consistency.

### **1008.02 Sampling, Testing and Inspection.**

- (a) Plant Inspection. Before manufacture of any paint is started, the paint materials shall be set aside at the manufacturer's plant and will be sampled by an authorized representative of the Department. All materials represented by these samples shall be held until tests have been made and the materials found to comply with the requirements of the Specifications. All tests will be made by and at the expense of the Department. The Department also retains the option to waive inspection and testing of ingredient materials.
- (b) Color. Where the color requirements of a paint vehicle is specified in terms of "Hellige Comparator", it will be determined with a Hellige Comparator No. 605 using Permanent Glass Color Standards, Disks Nos. 620 C-40 and 620 C-42. These disks are equivalent to Gardner Color Standards 1933.

**1008.03 Packing.** Unless otherwise directed, the paints shall be shipped in 20 L (5 gal) containers. Aluminum paint shall be shipped in double-compartment type containers. All containers shall be made of new metal not lighter than 0.607 mm (0.0239 in. 24 gage), may be either painted or galvanized, shall be of the same color and design for any one order, shall have lids of approximately the same diameter as the containers equipped with rubber gaskets, shall have bails with handles, and shall

be so designed that they may be stacked one upon the other in tiers at least four high.

All containers shall meet the latest requirements of the U. S. Department of Transportation for shipping paint.

The paints shall be measured by volume, the unit of measure being a L (gal) of 1000 cu m (231 cu in.) at 25 °C (77 °F). For the aluminum paint, the vehicle and the paste shall be packed separately in the containers in the proportions shown in the following table:

Quantity (L)	Paste Type	
	Vehicle (L)	Paste (kg)
20	16.26	3.90
4	3.25	0.78
2	1.63	0.39

Quantity (gal)	Paste Type	
	Vehicle (gal)	Paste (lb)
5	4.296	8.59
1	0.859	1.72
1/2	0.430	0.86

Each container shall bear a label which shows the kind of paint and the manufacturer's name. The lot number of the paint, and the month and year the paint is packaged shall be stenciled on the side of the container or included on the label.

PIGMENTS

**1008.04 Leafing Aluminum Pigment.** Leafing aluminum pigment shall be furnished in the paste form and shall conform to the requirements of ASTM D 962, Type II, Class B.

**1008.05 Nonleafing Aluminum Pigment.** Nonleafing aluminum pigment shall be furnished in the paste form and shall conform to the requirements of ASTM D 962, Type 4, Class B medium.

**1008.06 – 1008.14 Reserved.**

| **VEHICLES**

**1008.15 Petroleum Spirits.** Petroleum Spirits commercially known as "mineral spirits" shall consist only of petroleum distillates and shall conform to the requirements of ASTM D 235 Type I.

**1008.16 Turpentine.** Turpentine shall be "gum spirits" of turpentine and shall conform to the requirements of ASTM D 13.

**1008.17 Varnish.** (Phenolic Resin). This material shall be a long oil 100 percent phenolic resin varnish of maximum elasticity and durability, of a type suitable for exterior use with aluminum pigments, and shall be resistant to the effect of light, oil, and water. The oils used in the varnish shall be vegetable drying oils of a type necessary to meet the Specification requirements. The varnish shall conform to the following requirements:

Appearance:	Clear and transparent.
Color:	(Hellige Comparator), not darker than No. 18.
Toughness:	It shall pass a 120 percent Kauri reduction test.
Draft test:	It shall pass the draft test.
"Skinning":	The varnish shall show no "skinning" after 48 hours in a 3/4 filled, tightly closed container.

Cold water resistance:	A film of the varnish applied on a metal panel and air-dried for 72 hours, when submerged in cold water for 96 hours and then air dried for one hour, shall show no whitening, dulling, checking or other serious defects.
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Hot water resistance:	A film of the varnish applied on a metal panel and air-dried for 72 hours, when submerged in boiling water for 6 hours and then air dried for one hour, shall show no whitening, dulling, checking, or other serious defects.
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Working properties:	When thoroughly mixed with aluminum paste in the proportion of 240 g/L (2 lb/gal) of varnish, the paint shall have good leafing qualities, show satisfactory brushing and leveling properties, and shall not break or sag when applied to a vertical, smooth, steel surface.
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Drying time:	When the varnish is applied to a metal panel and allowed to dry in a vertical position, it shall set to touch in not less than two hours nor more than six hours and dry hard and tough in not more than 24 hours.
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Viscosity (Gardner-Holdt) .....	B to E
Flash point (Tag closed tester), not less than .....	30 °C (86 °F)
Nonvolatile matter, not less than .....	50%
Rosin (Liebermann-Storch test) .....	None

#### **1008.18        Reserved**

### **MIXED PAINT**

**1008.19 Aluminum Paint.** The aluminum paint shall be composed of aluminum paste and phenolic resin varnish.

The aluminum paint shall be mixed at the site of the work. When aluminum paint is to be used for the final field coat, only enough for one day's use shall be mixed at a time.

- (a) Materials. The aluminum paste shall meet the requirements of Article 1008.04, and the phenolic resin varnish of Article 1008.17.
- (b) Formula. The paint shall be formulated as follows:

Aluminum paste .....	907 g (2 lb)
Varnish (Phenolic Resin) .....	4 L (1 gal)

- (c) Properties. When the paint is applied to a metal panel and allowed to dry in a vertical position, it shall set to touch in not more than six hours, and dry hard and tough in not more than 24 hours. The paint shall be of such consistency that it will have satisfactory spreading, leveling and "leafing" qualities, and shall not break or sag when applied to a smooth, vertical surface.

**1008.20 Nonleafing Aluminum Paint.** The nonleafing aluminum paint shall be composed of nonleafing aluminum paste and phenolic resin varnish.

The nonleafing aluminum paint shall be mixed at the site of the work.

- (a) Materials. The nonleafing aluminum paste shall meet the requirements of Article 1008.05, and the phenolic resin varnish shall meet the requirements of Article 1008.17.
- (b) Formula. The paint shall be formulated as follows:

Nonleafing aluminum paste .....	907 g (2 lb)
Varnish .....	4 L (1 gal.)

- (c) Properties. When the paint is applied to a metal panel and allowed to dry in a vertical position, it shall set to touch in not more than six hours, and dry hard and tough in not more than 24 hours. The paint shall be of such consistency that it will have satisfactory spreading and leveling qualities and shall not break or sag when applied to a smooth, vertical surface. The paint shall be nonleafing.

**1008.21 Reserved**

**1008.22 Inorganic Zinc-Rich Primer.** This specification covers a solvent-base, multiple component, self curing alkyl silicate zinc-rich paint which cures without use of a separate curing solution. It is intended for use only on blast-cleaned steel and for spray application. Limited application by brush can be made.

The inorganic zinc-rich primer shall meet the requirements of AASHTO M300 Type I with the following additional requirement: The Volatile Organic Compounds (VOC) shall not exceed 340 g/L (2.8 lb/gal) for both shop and field painting as applied when tested in accordance with ASTM D3960.



- (a) **Qualification Samples and Tests.** The manufacturer shall supply to an independent test laboratory and to the Department, duplicate samples of the inorganic zinc-rich primer for evaluation. Prior to approval and use, the manufacturer shall submit a notarized certification of the independent laboratory, together with results of all tests, stating that this material meets the requirements as set forth herein. The certified test report shall state lot tested, manufacturer's name, product name, and date of manufacture. New certified tests results and samples for testing by the Department shall be submitted anytime the manufacturing process or paint formulation is changed. All costs of testing (other than tests conducted by the Department) shall be borne by the manufacturer.
- (b) **Acceptance Samples and Certification.** A 1 L (1 qt) sample of each lot of paint produced for use on State or local agency projects shall be submitted to the Department for testing, together with a manufacturer's certification. The certification shall state that the formulation for the lot represented is essentially identical to that used for qualification testing. All acceptance samples shall be taken by a representative of the Illinois Department of Transportation. The inorganic zinc-rich primer shall not be used until tests are completed and they have met the requirements as set forth herein.

#### **1008.23 Reserved.**

**1008.24 Waterborne Acrylic.** The acrylic primer and finish coat shall be a two-coat, waterborne, acrylic paint system for direct to metal application on prepared structural steel and for topcoating previously painted surfaces. The acrylic primer shall be suitable as an intermediate coat over inorganic and organic zinc primers, aluminum epoxy mastics, acrylics, vinyls, and alkyds. The acrylic finish coat shall be compatible as a topcoat over the primer.

The acrylic paints shall meet the requirements of the Steel Structures Painting Council's Painting System Specification No. 24.00 (Latex Painting System for Industrial and Marine Atmospheres, Performance-Based) as outlined in Volume 2, Systems and Specifications, Seventh Edition. The performance testing shall comply with Level I, except that Section 6.3 Early Rust Resistance of System shall be modified as follows:

6.3.1. Prepare and equilibrate an environmental chamber at 10 °C (50 °F) and approximately 75 – 80 percent R.H. Condition the paints to be applied and the panels in the environmental chamber for at least 45 minutes. If an environmental chamber is not available, a properly conditioned refrigerator with the same humidity and temperature conditions may be used.

6.3.2. Remove panels from the environmental chamber and apply one coat of primer, 35 - 45 microns (1.4 - 1.8 mils) dry above the profile, and return panels to the environmental chamber. After six hours, remove from the environmental chamber and allow to equilibrate for 30 minutes at ambient conditions for it to completely dry to touch (see notes 12.5 and 12.6).

6.3.3. Expose panels under continuous wet or condensing conditions at ambient temperature for approximately 16 hours (see note 12.7). At the end of 16 hours,

immediately examine for rusting. The rusting shall not exceed 9 as judged by ASTM D 610. Blistering may occur at this time, however, allow time for recovery by drying the test panel overnight before rating the blister. The rating shall not exceed 8F according to ASTM D 714.

- (a) Workability. The paints shall be easily applied by conventional and airless spray to smooth vertical surfaces at a minimum dry film thickness of 75 microns (3 mils) per coat without runs, sags, or other film defects. When application is made by brush or roller, multiple coats will be permitted to achieve 75 microns (3 mils) dry film thickness and uniformity of appearance.
- (b) Toxicity. The paints shall not contain more than trace amounts of lead, hexavalent chromium, cadmium, mercury, or other toxic heavy metals.
- (c) Flash Point. The flash point of the coatings shall be greater than 65 °C (149 °F) as determined by a Pensky-Martens Closed Cup Tester according to ASTM D 93.
- (d) Shelf Life. The paints shall show no curdling, gelling, gassing, or an increase in viscosity of more than 10 KU after one year from the date of manufacture when packaged in tightly covered unopened containers and stored at temperatures between 10 °C and 32 °C (50 °F - 90 °F).
- (e) Volume Solids. The coatings shall not be less the 32 percent solids by volume.
- (f) Odor. Freshly opened containers of the paints shall not exhibit any rancid, putrid, or other objectionable odors.
- (g) Drying Time. The paints shall set to touch within four hours and dry through within 24 hours when applied at 250 microns (10 mils) wet film thickness and tested according to ASTM D 1640.
- (h) Color and Hiding Power. The primer shall match Munsell Matte or Glossy Color 5Y 8/4 Yellow. The finish coat shall match Munsell Glossy Color 7.5G 4/8 Interstate Green, 2.5YR 3/4 Reddish Brown, 10B 3/6 Blue, or 5B 7/1 Gray. The color tolerance shall not exceed 10 Hunter Delta E Units for the primer and 3.0 Hunter Delta E Units for the finish coats. Color difference shall be measured by instrumental comparison of the designated Munsell standard to a minimum dry film thickness of 75 microns (3 mils) of sample coating produced on a test panel according to ASTM D 823, Practice E, Hand-Held, Blade Film Application. The contrast ratio of the finish coats at 50 microns (2 mils) dry film thickness shall not be less than 0.99 when tested according to ASTM D 2805. Color measurements shall be determined on a spectrophotometer with 45 degrees circumferential/0 degrees geometry, illuminant C, and 2 degrees observer angle. The spectrophotometer shall measure the visible spectrum for 380 - 720 nm with a wavelength interval and spectral bandpass of 10 nm.
- (i) Gloss. The 60 degrees specular gloss of the finish coats shall not be less than 65 when measured according to ASTM D 523.

- (j) **Color and Gloss Retention of Finish Coats.** A 250 micron (10 mil) wet film of finish coat shall be applied to a 300 mm x 100 mm (12 in. x 4 in.) aluminum alloy panel prepared according to ASTM D 1730 Type A, Method 1 Solvent Cleaning. Allow to air dry for seven days and then measure the 60° specular gloss and color. Subject the coated panel for 300 hours to accelerated weathering using the light and water exposure apparatus (fluorescent UV - condensation type) as specified in ASTM G 53 (equipped with UVB-313 lamps). The cycle shall consist of eight hours UV exposure at 60° C (140° F) followed by four hours of condensation at 40 °C (104 °F). After exposure, rinse the panel with clean water, allow to dry at room temperature for one hour, and again measure the 60 degrees specular gloss and color. The panel shall not show a color change of more than 3 Hunter Delta E Units and the 60 degrees specular gloss shall not be less than 40.
- (k) **Adhesion to Inorganic Zinc.** The acrylic paints shall pass the topcoat adhesion test as specified in AASHTO M300. The inorganic zinc-rich primer shall meet the requirements of Article 1008.22.
- (l) **Qualification Samples and Tests.** The manufacturer shall supply to an independent test laboratory and to the Department, duplicate samples of the waterborne acrylic paints for evaluation. Prior to approval and use, the manufacturer shall submit a notarized certification of the independent laboratory, together with results of all tests, stating that these materials meet the requirements as set forth herein. Independent laboratory tests shall be required for each finish coat color the manufacturer proposes to supply. The certified test report shall state lot tested, manufacturer's name, product name, and date of manufacture. New certified test results and samples for testing by the Department shall be submitted any time the manufacturing process of paint formulation is changed. All costs of testing (other than tests conducted by the Department) shall be borne by the manufacturer.
- (m) **Acceptance Samples and Certification.** A 1 L (1 qt) sample of each lot of paint produced for use on state or local agency projects shall be submitted to the Department for testing, together with a manufacturer's certification. The certification shall state that the formulation for the lot represented is essentially identical to that used for qualification testing. All acceptance samples shall be taken by a representative of the Illinois Department of Transportation. The waterborne acrylic paints shall not be used until tests are completed and they have met the requirements as set forth herein.
- (n) **Packaging and Labeling.** Each container shall have a label clearly showing the manufacturer, product name, lot number, date of manufacture, and shelf life. The label shall also include complete instructions for use of the product. The container shall be coated, if necessary, to prevent attack by the paint components.

**1008.25 Aluminum Epoxy Mastic.** The aluminum epoxy mastic shall be a two component epoxy primer containing aluminum pigment designed as a one coat high-build complete protective coating system with excellent adhesion to rusted steel, inorganic zinc, and old paint after such surfaces have been properly cleaned. The aluminum epoxy mastic shall be compatible with a wide range of topcoats including waterborne acrylics, alkyds, and polyurethane.

- (a) **Pigment.** The primary pigment shall be either a leafing or non-leafing aluminum pigment. Secondary pigmentation shall not contain more than trace amounts of lead, chromium, or other toxic heavy metals.
- (b) **Vehicle.** The vehicle shall be a modified epoxy and curing agent which is suitably insensitive to moisture to allow trouble free application.
- (c) **Packaged Components.** The epoxy coating shall be supplied as a two-component material at a one-to-one volume mix ratio. It shall be well ground, free of caking, skins, gellation, and excessive settling. The shelf life of each component shall be not less than twelve months.
- (d) **Properties of Aluminum Epoxy Mastic.**
  - (1) The mixed epoxy shall contain a minimum of 89 percent solids by weight, when tested according to ASTM D 1644, Method A, except that the sample shall be heated for 72 hours at  $37.8^{\circ}\text{C} \pm 1^{\circ}\text{C}$  ( $100^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ).
  - (2) The unit weight of the unmixed components shall not vary more than  $\pm 24$  g/L (0.2 lb/gal) from the weight of the original qualification samples.
  - (3) The viscosity of the coating shall be a minimum of 85 KU at  $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$  ( $77^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ). Viscosity must be checked immediately after addition and mixing of components.
  - (4) The pot life of the epoxy coating shall be no shorter than two hours at  $24^{\circ}\text{C}$  ( $75^{\circ}\text{F}$ ) or one hour at  $32^{\circ}\text{C}$  ( $90^{\circ}\text{F}$ ).
  - (5) The epoxy coating shall air cure at a temperature of  $24^{\circ}\text{C}$  ( $75^{\circ}\text{F}$ ) or above to a hard tough film within five days, by evaporation of solvent and chemical reaction. It shall be dry to the touch in 24 hours at  $24^{\circ}\text{C}$  ( $75^{\circ}\text{F}$ ), and to receive foot traffic in 48 hours at  $24^{\circ}\text{C}$  ( $75^{\circ}\text{F}$ ).
  - (6) The mixture, when thinned per manufacturer's recommendations, shall exhibit no run or sags, when applied by conventional or airless spray to produce dry film thicknesses in the 125 to 175 microns (5 to 7 mil) range.
  - (7) The Volatile Organic Compounds (VOC) shall not exceed 340 g/L (2.8 lb/gal) as applied when tested according to ASTM D 3960.
- (e) **Resistance Tests of Cured Aluminum Epoxy Mastic.** Test panels of steel meeting the requirements of ASTM D 609, having dimensions of 50 x 125 x 3 mm (2 x 5 x 1/8 in.) shall be prepared by sandblasting all surfaces to a white metal finish according to Structural Steel Painting Council SP5 (SSPC-SP5). The cleaned panels shall then be exposed to outdoor weather for 30 days or until uniform rusting occurs. They shall then be hand cleaned with a wire brush according to SSPC-SP2. A 150 micron (6 mil) dry film of the

epoxy mastic shall then be applied in one coat according to the manufacturer's current printed instructions. The coating shall be cured as recommended by the manufacturer. Each of the following tests shall be performed on one or more test panels. Test panels that must be scribed shall be prepared according to the requirements in ASTM D 1654. The material will not be accepted if any individual test panel fails any on the following tests:

- (1) Fresh Water Resistance. Panels shall be scribed down to base metal with an "X" of at least 50 mm (2 in.) legs and shall be immersed in fresh tap water at  $24^{\circ}\text{C} \pm 3^{\circ}\text{C}$  ( $75^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ). The panels shall show no rusting, blistering, or softening beyond 1.6 mm (1/16 in.) from the scribe mark, when examined after 30 days. Discoloration of the coating will be allowed.
  - (2) Salt Water Resistance. Panels shall be scribed down to base metal with an "X" of at least 50 mm (2 in.) legs and immersed in five percent sodium chloride at  $24^{\circ}\text{C} \pm 3^{\circ}\text{C}$  ( $75^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ). The panels shall show no rusting, blistering, or softening beyond 1.6 mm (1/16 in.) from the scribe mark upon examination after 7, 14, and 30 days. Discoloration of the coating will be allowed. The sodium chloride solution shall be replaced with fresh solution after each examination.
  - (3) Salt Fog Resistance. Panels shall be scribed down to base metal with an "X" of at least 50 mm (2 in.) legs. The panels shall then be tested according to ASTM B 117. After 1,000 hours of continuous exposure, the coating shall show no loss of bond, nor shall it show rusting or blistering beyond 1.6 mm (1/16 in.) from the center of the scribed mark.
  - (4) Weathering Resistance. Panels shall be tested in accelerated weathering using either the light and water exposure apparatus (fluorescent UV-condensation type) as specified in ASTM G 53 for 1,000 hours with a cycle consisting of eight hours UV exposure at  $60^{\circ}\text{C}$  ( $140^{\circ}\text{F}$ ) followed by four hours of condensation at  $40^{\circ}\text{C}$  ( $104^{\circ}\text{F}$ ), or the weatherometer according to ASTM G 23, Type D for 1,000 hours beginning the test at the start of the wet cycle. After this period, the panels shall show no loss of bond, nor shall they show rusting, softening, or blistering.
- (f) Qualification Samples and Tests. The manufacturer shall supply to an independent test laboratory and to the Department, duplicate samples of the aluminum epoxy mastic for evaluation. Prior to approval and use, the manufacturer shall submit a notarized certification of the independent laboratory, together with results of all tests, stating that these materials meet the requirements as set forth herein. The certified test report shall state lot tested, manufacturer's name, product name, and the date of manufacture. New certified test results and samples for testing by the Department shall be submitted any time the manufacturing process or paint formulation is changed. All costs of testing (other than tests conducted by the Department) shall be borne by the manufacturer.

- (g) Acceptance Samples and Certification. A 1 L (1 qt) sample of each lot of paint produced for use on state or local agency projects shall be submitted to the Department for testing, together with a manufacturer's certification. The certification shall state that the formulation for the lot represented is essentially identical to that used for qualification testing. All acceptance samples shall be taken by a representative of the Illinois Department of Transportation. The aluminum epoxy mastic shall not be used until tests are completed and they have met the requirements as set forth herein.
- (h) Packaging and Labeling. The aluminum epoxy mastic coating shall be packaged in two containers. The components shall be prepackaged such that mixing on a one-to-one ratio, by volume, utilizes a complete container of each component. Each container shall have a label clearly showing the manufacturer, product name, lot number, date of manufacture, and shelf life. The label on either the epoxy or curing agent shall also include complete instructions for use of this paint. The container shall be coated, if necessary, to prevent attack by the paint components.

## SECTION 1009. BITUMINOUS MATERIALS

**1009.01 Description.** Bituminous materials shall include asphalt cements, asphalt fillers, emulsified asphalts, rapid curing liquid asphalts, medium curing liquid asphalts, slow curing liquid asphalts, and road oils. All bituminous materials used in a given construction shall be uniform in character, appearance and consistency.

**1009.02 Sources of Supply.** All sources of supply shall be approved by the Engineer before delivery is started. If sources previously accepted are found to be unacceptable to the Engineer, the Contractor will be required to furnish materials from other approved sources.

The Contractor shall submit to the Engineer a statement giving the sources of the bituminous materials he/she proposes to use. Only bituminous materials from these sources shall be used on the work unless approval, in writing, is obtained from the Engineer.

**1009.03 Measurement of Volume.** Measurement of the volume of asphalt cements, asphalt fillers, emulsified asphalts, rapid curing liquid asphalts, medium curing liquid asphalts, slow curing liquid asphalts and road oils will be based on the volume of the material at 15.6 °C (60 °F). Volumes measured at higher or lower temperatures will be corrected to the volume at 15.6 °C (60 °F), using the Standard ASTM-IP Petroleum Measurement Tables, ASTM D 1250.

Payment will not be made for bituminous materials in excess of 105 percent of the amount specified by the Engineer.

If bituminous materials are delivered by tank truck from a refinery or from a storage tank, a weight ticket for each truck load shall be furnished the Inspector. It shall show the weight of the empty truck (the truck being weighed each time before it is loaded), the weight of the loaded truck, and the net weight of the bituminous material. If the material is being paid for by the liter (gallon), the specific gravity at

15.6 °C/15.6 °C (60 °F/60 °F) of the bituminous material in the tank truck and the number of liters (gallons) at 15.6 °C (60° F) shall be shown on the weight ticket. The scales shall be approved by the Engineer.

**1009.04 Delivery.** When bituminous materials are not approved at the source by the Department, they shall be delivered far enough in advance of their use on the work to permit the necessary tests to be made. When not delivered in tank cars or tank trucks, the bituminous materials shall be delivered in suitable containers or packages, plainly labeled to show the kind of material, the name of manufacturer, and the lot or batch number. Each shipment and each carload shall be kept separate until the material has been accepted.

Asphalt cement when delivered in tank cars or tank trucks, shall be delivered at a temperature not to exceed 175 °C (350 °F).

Petroleum Asphalts PAF-1 and PAF-2 shall be shipped in new, double end, metal drums. The thickness of the metal used shall not be less than 0.4 mm (0.0149 in.). The side seams of the drums shall be double lapped, spot welded single lapped, or stitch welded single lapped. The seams shall meet the approval of the Engineer. The drums shall be manufactured so that there will be no leakage during hot weather. The capacity of each drum shall be approximately 210 kg (460 lb), the drums being 890 mm (35 in.) maximum in height and approximately 560 mm (22 in.) in diameter.

Petroleum Asphalts PAF-3 and PAF-4 shall be shipped in new, open end, metal drums. The thickness of the metal used shall be not less than 0.4 mm (0.0149 in.). The seams shall be constructed so that the filled drums will withstand shipping and handling. The inside of the drums shall be coated with talc or other approved material to facilitate peeling. The capacity of each drum shall be approximately 210 kg (460 lb), the drums being 890 mm (35 in.) maximum in height and approximately 560 mm (22 in.) in diameter. Petroleum Asphalts PAF-3 and PAF-4 may, when specified, be shipped in approved 45 kg (100 lb) cartons.

**1009.05 Asphalt Cement (Prepared from Petroleum).** These materials will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Performance Graded Asphalt Binder Acceptance Procedure". These materials shall be free from water and shall not foam when heated to any temperature below the actual flash point. They shall conform to the requirements listed in the following table:

When requested, producers shall provide the Engineer with viscosity/temperature relationships for the performance graded asphalt cements delivered and incorporated in the work.

- (a) Performance Graded (PG) Asphalt Cement. The asphalt cement shall meet the requirements of AASHTO MP 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown on the plans. Air blown asphalt will not be allowed.
- (b) Modified Performance Graded (PG) Asphalt Cement. The asphalt cement shall meet the requirements of AASHTO MP 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown

on the plans. Elastomers shall be added to the base asphalt cement to achieve the specified performance grade and shall be either a styrene butadiene diblock or triblock copolymer without oil extension or a styrene butadiene rubber. Air blown asphalts and other modifiers will not be allowed. Asphalt modification at bituminous mixture plants will not be allowed. The modified asphalt cement shall be smooth, homogeneous, and comply with the requirements given in Table 1 or 2 for the grade shown on the plans.

Table 1  
Requirements for Styrene-Butadiene Copolymer (SBS) Modified Asphalt Cements

Test	Asphalt Grade SBS PG64-28 SBS PG70-22 SBS PG70-28	Asphalt Grade SBS PG76-22 SBS PG76-28
Separation of Polymer <sup>1/</sup> 163 °C (325 °F), 48 hours, difference in R & B from top to bottom sample. °C (°F), maximum	2 (4)	2 (4)
Force Ratio <sup>2/</sup> (f <sub>2</sub> /f <sub>1</sub> ), 4 °C (39.2 °F), 50 mm/min., 300 mm elongation, minimum	0.3	0.35
TESTS ON RESIDUE FROM ROLLING THIN FILM OVEN TEST		
Elastic Recovery <sup>3/</sup> , 25 °C (77 °F), 100 mm elongation % minimum	60	70

Table 2  
Requirements for Styrene-Butadiene Rubber (SBR) Modified Asphalt Cements

Test	Asphalt Grade SBR PG64-28 SBR PG70-22 SBR PG70-28	Asphalt Grade SBR PG76-22 SBR PG76-28
Separation of Polymer <sup>1/</sup> 163 °C (325 °F), 48 hours, difference in R & B from top to bottom sample. °C (°F), maximum	2 (4)	2 (4)
Toughness <sup>4/</sup> , 25 °C (77 °F), 500 mm/min. (20 in./min.), Newton-meters (in.-pounds), minimum	12.5 (110)	12.5 (110)
Tenacity <sup>4/</sup> , 25 °C (77 °F), 500 mm/min, (20 in./min.), Newton-meters (in.-pounds)	8.5 (75)	8.5 (75)
TESTS ON RESIDUE FROM ROLLING THIN FILM OVEN TEST		
Elastic Recovery <sup>3/</sup> , 25 °C (77 °F), 100 mm, elongation % minimum 4 in.	40	50

1/ The separation of polymer from asphalt shall be evaluated as follows:

Carefully heat the sample avoiding localized overheating, until sufficiently fluid to pour.



Strain the melted sample through a 300  $\mu\text{m}$  (No. 50) sieve and stir thoroughly.

Pour 50.0 grams of sample into a thin-wall aluminum tube having approximate dimensions of 25 mm (1 in.) diameter by 140 mm ( 5 1/2 in.) length. Fold the excess tube over two times and crimp to seal.

Place the sealed tube vertically in a  $163 \pm 6\text{ }^{\circ}\text{C}$  ( $325 \pm 10\text{ }^{\circ}\text{F}$ ) oven. Allow the tube to stand, undisturbed, in the oven for a period of  $48 \pm 1$  hours. At the end of the heating period, immediately place the tube in a freezer at  $-7 \pm 6\text{ }^{\circ}\text{C}$  ( $20 \pm 10\text{ }^{\circ}\text{F}$ ), keeping the tube in a vertical position at all times. Leave the tube in the freezer for a minimum of four hours to completely solidify the sample.

Upon removing the tube from the freezer, place on a hard flat surface and cut the tube into three equal length portions with a sharp spatula and hammer. Place the top and bottom portions into separate marked beakers and heat in a  $163 \pm 6\text{ }^{\circ}\text{C}$  ( $325 \pm 10\text{ }^{\circ}\text{F}$ ) oven until sufficiently fluid.

Remove the pieces of aluminum tube, stir thoroughly, and pour the top and bottom samples into marked softening point rings. Determine the softening point of the top and bottom portions of the sample simultaneously according to AASHTO T 53.

2/ The force ratio is defined as the force at 300 mm elongation ( $f_2$ ) divided by the maximum force at the initial peak ( $f_1$ ) and shall be determined according to AASHTO T 300.

3/ The elastic recovery shall be performed according to AASHTO T 51 with the following modifications:

The standard v-shaped sides for the specimen mold shall be replaced by straight-sided inserts of the same length so the specimen will contain a section 10 mm x 30 mm.

The sample shall be elongated to 100 mm and then immediately cut approximately in half with scissors.

After one hour in the bath, the ends of the cut sample shall be brought together to just touch and the length of the recovered sample measured and recorded as A. The percent elastic recovery (R) shall be calculated as follows:

$$R = 100 - A$$

4/ Toughness and tenacity shall be determined according to ASTM D 5801.

**1009.06 Asphalt Fillers (Prepared from Petroleum).** These materials shall be free from water and shall not foam when heated to the flash point. They shall conform to the requirements listed in the following table:

Test	Grades			
	PAF-1	PAF-2	PAF-3	PAF-4
Flash point (Cleveland open cup), °C	232+	232+	232+	246+
Softening point (ring and ball method), °C	50+	57+	75 to 85	82+
Penetration at 0 °C, 200g, 60 sec	30+	15+	10+	15+
Penetration at 25 °C, 100g, 5 sec	80 to 100	40 to 55	25 to 40	30 to 50
Penetration at 45 °C, 50g, 5 sec	---	190-	90-	80-
Loss on heating at 163 °C, 50 g, 5 hrs., percent	1.0-	1.0-	1.0-	1.0-
Penetration at 25 °C, 100 g., 5 sec., of asphalt after heating at 163 °C, as compared with penetration of asphalt before heating, percent	70.0+	70.0+	70.0+	70.0+
Ductility at 25 °C, cm	40+	15+	2.5+	2.5+
Bitumen soluble in trichloroethylene, percent	99.0 +	99.0+	99.0+	99.0+

Test (English Units)	Grades			
	PAF-1	PAF-2	PAF-3	PAF-4
Flash point (Cleveland open cup), °F	450+	450+	450+	475+
Softening point (ring and ball method), °F	122+	135+	167 to 185	180+
Penetration at 32 °F, 200g, 60 sec	30+	15+	10+	15+
Penetration at 77 °F, 100g, 5 sec	80 to 100	40 to 55	25 to 40	30 to 50
Penetration at 115 °F, 50g, 5 sec	---	190-	90-	80-
Loss on heating at 325 °F, 50 g, 5 hrs., percent	1.0-	1.0-	1.0-	1.0-
Penetration at 77 °F, 100 g., 5 sec., of asphalt after heating at 325 °F, as compared with penetration of asphalt before heating, percent	70.0+	70.0+	70.0+	70.0+
Ductility at 77 °F, cm	40+	15+	2.5+	2.5+
Bitumen soluble in trichloroethylene, percent	99.0 +	99.0+	99.0+	99.0+

The different grades are, in general, used for the following:

- PAF-1 & PAF-2 - For filling cracks in portland cement concrete pavement.
- PAF-3 - For sealing expansion and contraction joints in portland cement concrete pavement and for undersealing portland cement concrete pavement.
- PAF-4 - For sealing expansion and contraction joints in portland cement concrete pavement and for filler in brick pavement.

**1009.07 Emulsified Asphalts.** Emulsified asphalts will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Emulsified Asphalt Acceptance Procedure". These materials shall be homogeneous and shall show no separation of asphalt after thorough mixing, within 30 days after delivery, provided separation has not been caused by freezing. They shall coat the aggregate being used in the work to the satisfaction of the Engineer and shall conform to the following requirements:

- (a) Anionic Emulsified Asphalt. Anionic emulsified asphalts shall conform with the requirements of AASHTO M 140.
- (b) Cationic Emulsified Asphalt. Cationic emulsified asphalts shall conform with the requirements of AASHTO M 208.
- (c) High Float Emulsion. High float emulsion shall meet the requirements listed in the following table:

HIGH FLOAT EMULSION				
Medium Setting				
TEST	HFE-60	HFE-90	HFE-150	HFE-300
Viscosity, Saybolt Furol, at 50 °C (122 °F), sec	50+*	50+*	50+*	50+*
Sieve test (850 µm) (No. 20), retained on sieve, percent	0.10-	0.10-	0.10-	0.10-
Settlement, percent <sup>1/</sup>	5-	5-	5-	5-
Storage Stability test, 1 day <sup>2/</sup>	1-	1-	1-	1-
Distillation test: Residue from distillation test to 260 °C (500 °F), percent	65+	65+	65+	65+
Oil distillate, by volume percent	7-	7-	7-	7-
Characteristics of residue from distillation Test to 260 °C (500 °F), Penetration at 25 °C (77 °F), 100 g, 5 sec	60-90	90-150	150-300	300+
Coating test (All Grades)	3 minutes , stone coated thoroughly			
Float test at 60 °C (140 °F), sec	1200+	1200+	1200+	1200+

\* And Pumpable

- 1/ The test requirement for settlement may be waived when the emulsified asphalt is used in less than five days time; or the purchaser may require that

the settlement test be run from the time the sample is received until it is used, if the elapsed time is less than five days.

- 2/ The 24 hour (one-day) storage stability test may be used instead of the five-day settlement test.
- (d) Penetrating Emulsified Prime (PEP). The penetrating emulsified prime shall meet the following requirements when tested according to AASHTO T59:

Viscosity, Saybolt Furol, at 25 °C (77 °F), max. seconds.....	75
Sieve test, retained on 850 µm (No. 20) sieve, max. percent .....	0.10
Distillation to 260 °C (500 °F)Residue, min. percent .....	38
Oil distillate by volume, max. percent.....	4

In addition, the PEP shall pass the following sand penetration test:

The standard reference sand for this test shall be a natural silica type, composed almost entirely of naturally rounded grains of nearly pure quartz, and shall be graded as follows:

Sieve	180 µm (No. 80)	150 µm (No. 100)	106 µm (No. 140)	75 µm (No. 200)
Percent Passing	99±1	97±3	50±5	2±2

Dampen 312.5 g of reference sand with 5.0 g of water. Place the moistened sand into a cylindrical metal container having a nominal capacity of 235 ml (8 oz), and compress at 690 kPa (100 psi). Measure 5 g of prime into the container of compacted sand and record the time for penetration in seconds. Remove a cross section of the sand and record the depth of penetration in millimeters. The time of penetration shall be equal to or less than that of MC-30. The depth of penetration shall be equal to or greater than that of MC-30.

- (e) Latex Modified Emulsified Asphalt. The 100 percent natural latex modifier added at a minimum of 2.5 percent natural rubber solid by weight of binder (asphalt & rubber) and other emulsifiers shall be milled into the asphalt cement and shall show no separation after mixing. The latex modified CSS-1h Emulsified Asphalt shall meet the following requirements:

Viscosity, Saybolt Furol at 25 °C (77 °F), seconds .....	15-100
Storage stability test, 24 hours, percent maximum .....	1
Particle charge test .....	positive
Sieve test, percent, maximum .....	0.10
*Distillation residue, percent minimum .....	62
Tests on residue from distillation:	
Penetration, 25 °C (77 °F), 100 grams, 5 seconds .....	40-80
Ductility, 25 °C (77 °F), 5 cm/min, cm, minimum .....	50
Solubility in trichloroethylene, percent, minimum .....	97.5
Softening point, °C (°F), minimum .....	60 (140)
Viscosity, 60 °C (140 °F), Pa s (poises), minimum .....	800 (8000)

\*The distillation for latex modified emulsion shall be performed according to AASHTO T-59 except the temperature shall be changed from  $260 \pm 5^{\circ}\text{C}$  ( $500 \pm 9^{\circ}\text{F}$ ) to  $175 \pm 5^{\circ}\text{C}$  ( $347 \pm 9^{\circ}\text{F}$ ).

The different grades are, in general, used for the following:

SS-1, SS-1h, CSS-1, CSS-1h, HFE 60, HFE 90	For tack or fog seal.
PEP	For bituminous surface treatment prime.
RS-1, RS-2, CRS-1, CRS-2, HFE 90, HFE 150, HFE 300	For bituminous surface treatment.
MS-1, MS-2, SS-1, CMS-1, CMS-2, CSS-1, HFE 150, HFE 300	For coarse graded aggregate mixes.
MS-2, HFE 90, HFE 150, HFE 300	For machine mix surfaces, open graded aggregate mixes.
SS-1, HFE 300	For fine graded aggregate mixes.
SS-1, SS-1h, CSS-1, CSS-1h Latex Modified	For asphalt coated mulch. For microsurfacing.

**1009.08 Rapid Curing Liquid Asphalts.** Rapid curing liquid asphalts will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Cut-back Asphalt and Road Oil Acceptance Procedure." These materials shall be rapid curing cut-back asphalts consisting of a petroleum residuum fluxed with a suitable distillate. They shall be free from water, show no separation on standing, and shall conform to the requirements listed in the following table:

Test	GRADES			
	RC-70	RC-250	RC-800	RC-3000
Flash point (Tag open cup), °F	--	80+	80+	80+
Flash point (Tag open cup), °C	--	27+	27+	27+
Viscosity, Kinematic, at 60 °C (140 °F), sq mm /sec (cSt)	70 to 140	250 to 500	800 to 1600	3000 to 6000
Distillation test:				
Distillate, percent by volume of total distillate 360 °C (680 °F)				
Distillate to 190 °C (374 °F)	10+	--	--	--
Distillate to 225 °C (437 °F)	50+	35+	15+	--
Distillate to 260 °C (500 °F)	70+	60+	45+	25+
Distillate to 315 °C (600 °F)	85+	80+	75+	70+
Residue from distillation to 360 °C (680 °F), Percent volume by difference	55+	65+	75+	80+
Tests on residue from distillation:				
Penetration at 25 °C (77 °F), 100 g, 5 sec	80 to 120	80 to 120	80 to 120	80 to 120
Ductility at 25 °C (77 °F), cm/2	100+	100+	100+	100+
Bitumen soluble in trichloroethylene, Percent	99.5+	99.5+	99.5+	99.5

**1009.09 Medium Curing Liquid Asphalts.** Medium curing Liquid asphalts will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Cut-back Asphalt and Road Oil Acceptance Procedure". These materials shall be medium curing cut-back asphalts consisting of a petroleum residuum fluxed with a suitable distillate. They shall be free from water, show no separation on standing, and shall conform to the requirements listed in the following table:

Test	Grades				
	MC-30	MC-70	MC-250	MC-800	MC-3000
Flash point (Tag open cup), °C 1/	38+	38+	--	--	--
Flash point (Cleveland open cup), °C	--	--	65+	65+	65+
Viscosity, Kinematic, at 60 °C, sq mm /sec.	30 to 60	70 to 140	250 to 500	800 to 1600	3000 to 6000
Distillation test					
Distillate, percent by volume of total distillate to 360 °C					
Distillate to 225 °C	25-	20-	10-	--	--
Distillate to 260 °C	40 to 70	20 to 60	15 to 55	35-	15-
Distillate to 315 °C	75 to 93	70 to 90	60 to 87	45 to 80	15 to 75
Residue from distillation to 360 °C, percent volume by difference	50+	55+	67+	75+	80+
Tests on residue from distillation					
Penetration at 25 °C, 100 g, 5 sec	120 to 250	120 to 250	120 to 250	120 to 250	120 to 250
Ductility at 25 °C, cm 2/	100+	100+	100+	100+	100+
Bitumen soluble in trichloroethylene, Percent	99.5+	99.5+	99.5+	99.5+	99.5+

Test	Grades				
	MC-30	MC-70	MC-250	MC-800	MC-3000
Flash point (Tag open cup), °F1/	100+	100+	---	---	---
Flash point (Cleveland open cup), °F	---	---	150+	150+	150+
Viscosity, Kinematic, at 140 °F, cSt	30 to 60	70 to 140	250 to 500	800to 1600	3000 to 6000
Distillation test					
Distillate, percent by volume of total distillate to 680 °F					
Distillate to 437 °F	25-	20-	10-	--	--
Distillate to 500 °F	40 to 70	20 to 60	15 to 55	35-	15-
Distillate to 600 °F	75 to 93	70 to 90	60 to 87	45 to 80	15 to 75
Residue from distillation to 680 °F, percent volume by difference	50+	55+	67+	75+	80+
Tests on residue from distillation					
Penetration at 77 °F, 100 g, 5 sec	120 to 250	120 to 250	120 to 250	120 to 250	120 to 250
Ductility at 77 °F, cm 2/	100+	100+	100+	100+	100+
Bitumen soluble in trichloroethylene, Percent	99.5+	99.5+	99.5+	99.5+	99.5+

1/ Flash point by Cleveland open cup may be used for products having a Flash Point greater than 80 °C (175 °F)

2/ If ductility is less than 100, the material will be acceptable if the ductility is 100 + at 15 °C (60 °F).

The different grades are, in general, used for the following:

- MC-30 and MC-70 - For prime coats.
- MC-250 - For road mix surfaces dense-graded aggregate type.
- MC-800 - For traveling plant mix surfaces dense-graded aggregate type, for surface treatment and for seal coat.
- MC-3000 - For modified plant mix surfaces dense-graded aggregate type, for surface treatment and for seal coat.

**1009.10 Slow Curing Liquid Asphalts.** Slow curing liquid asphalts will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Cut-back Asphalt and Road Oil Acceptance Procedure". These materials shall be slow curing liquid asphalts produced by the distillation of petroleum. The liquid asphalts shall be residues, distillates or residues fluxed to the desired consistency with petroleum distillates. Each shipment of liquid asphalt shall be uniform in appearance and consistency. All grades shall be free from water and shall not foam when heated to 107 °C (225 °F) The residues of specified penetration shall be smooth and homogeneous in appearance. These materials shall conform to the requirements listed in the following table:

Test	Grades			
	SC-70	SC-250	SC-800	SC-3000
Flash point (Cleveland open cup), °C	65+	80+	93+	107+
Viscosity, Kinematic, at 60 °C, sq mm /sec.	70 to 140	250 to 500	800 to 1600	3000 to 6000
Residue of 100 penetration, percent	50+	60+	70+	80+
Ductility at 25 °C, of residue of specified Penetration, cm	100+	100+	100+	100+
Loss on heating at 163 °C, 50 g, 5 hours, Percent	11-	8-	5-	4-
Bitumen soluble in trichloroethylene, Percent	99.0+	99.0+	99.5+	99.5+



Test	Grades			
	SC-70	SC-250	SC-800	SC-3000
Flash point (Cleveland open cup), °F	150+	175+	200+	225+
Viscosity, Kinematic, at 140 °F, cSt	70 to 140	250 to 500	800 to 1600	3000 to 6000
Residue of 100 penetration, percent	50+	60+	70+	80+
Ductility at 77 °F, of residue of specified Penetration, cm	100+	100+	100+	100+
Loss on heating at 325 °F, 50 g, 5 hours, Percent	11-	8-	5-	4-
Bitumen soluble in trichloroethylene, Percent	99.0+	99.0+	99.5+	99.5+

The different grades are, in general, used for the following:

- SC-70 - For dust layer and for prime coats.
- SC-250 - For road mix and traveling plant mix surfaces dense-graded aggregate type.
- SC-800 - For plant mix surfaces dense-graded aggregate type.
- SC-3000 - For plant mix surfaces dense-graded aggregate type, for surface treatment, and for seal coat.

**1009.11 Road Oils.** (For surface treatment of earth roads.) Road Oils will be accepted according to the latest revision of the Bureau of Materials and Physical Research Policy Memorandum, "Cut-back Asphalt and Road Oil Acceptance Procedure". These materials shall be slow curing asphaltic oils. They shall show no separation on standing and shall conform to the requirements listed in the following table:

Test	Grades		
	E-2 Light	E-3 Medium	E-4 Heavy
Water, by volume, percent	0.5-	0.5-	0.5-
Flash Point (Cleveland open cup) °C	93+	93+	93+
Flash Point (Cleveland open cup) (°F)	(200+)	(200+)	(200+)
Viscosity, Kinematic, at 50 °C (122 °F) sq mm /sec. (cSt),	168 to 285	285 to 510	510 to 785
Viscosity, Saybolt Furol, at 50 °C (122 °F), sec	80 to 135	135 to 240	240 to 370
Bitumen soluble in trichloroethylene, percent	99.5+	99.5+	99.5+
Residue of 100 penetration, percent	50+	55+	60+
Ductility at 25 °C (77 °F), of residue of specified penetration, cm	100+	100+	100+

SECTION 1010. FLY ASH

**1010.01 Description.** Fly ash shall consist of the finely divided residue that results from the combustion of ground or powdered coal, transported from the combustion chamber by exhaust gas, collected by mechanical or electrical means, and stored in stockpiles or bins. The Department's Policy Memorandum, "Acceptance Procedure for Finely Divided Minerals Used in Portland Cement Concrete and Other Applications" will be used to approve Fly Ash.

**1010.02 Pozzolanic Mixtures (Lime-Fly Ash or Cement-Fly Ash).** The fly ash shall meet the requirements of AASHTO M 295, Class C, or Class F, except that if dampened for the purpose of transportation, the loss-on-ignition shall not exceed ten percent. Fly ash moisture content shall not exceed 35 percent. The fly ash when dry sieved according to Illinois Modified AASHTO T 27 shall meet the following gradation:

<u>Sieve</u>	<u>Minimum Percent Passing</u>
12.5 mm (1/2 in.)	100%
9.5 mm (3/8 in.)	95%
2.00 mm (No.10)	75%

**1010.03 Portland Cement Concrete and Cement Aggregate Mixture II.** The fly ash shall meet the standard physical and chemical requirements of AASHTO M 295, Class C or F. A limitation of available alkalis, as Na<sub>2</sub>O, of 1.5 percent, shall apply to fly ashes used in portland cement concrete mixtures and cement aggregate mixture II containing alkali-sensitive aggregates or admixtures.

Different sources or types of fly ash shall not be mixed or used alternately in the same item of construction unless approved by the Engineer.

**1010.04 Mineral Filler in Bituminous Mixtures.** The fly ash shall meet the requirements of AASHTO M 295, Class C, or Class F except if dampened for the purpose of transportation, the loss-on-ignition shall not exceed 12 percent.

SECTION 1011. MINERAL FILLER

**1011.01 Description.** Mineral filler shall consist of dry limestone dust, or other material approved by the Engineer, conforming to the following requirements:

Passing	600 µm (No. 30) sieve .....	100%
Passing	150 µm (No. 100) sieve .....	92 ± 8%
Passing	75 µm (No. 200) sieve .....	82 ± 18%

The source of supply shall be approved by the Engineer. When mineral filler is used in bituminous concrete, the Contractor shall submit to the Engineer a statement

giving the source of the mineral filler. Only mineral filler from this source shall be used on the job unless approval in writing is obtained from the Engineer.

SECTION 1012. LIME

**1012.01 Hydrated Lime.** Hydrated lime shall conform to the requirements of ASTM C 207, Type N. When used in pozzolanic aggregate mixture, the following modifications to ASTM C 207 shall apply:

- (a) Total calcium and magnesium oxides (nonvolatile basis) min. percent .... 90
- (b) Calcium oxide in hydrated lime (as received basis) max. percent ..... 5
- (c) Magnesium hydroxide (as received basis) max. percent ..... 5
- (d) Mechanical moisture in hydrated lime (as received basis) max. percent ... 4
- (e) Residue - The sieve analysis of the lime residue shall be as follows:

<u>Sieve</u>	<u>Maximum Percent Retained</u>
4.75 mm (No. 4)	0
600 µm (No. 30)	2.5
150 µm (No. 100)	15

**1012.02 Reserved.**

**1012.03 By-Product Lime for Lime Modified Soils.** When used in lime modified soils, by-product lime shall be either hydrated or non-hydrated conforming to the following requirements:

- (a) Total calcium and magnesium oxides (nonvolatile basis) min. percent.... 60
- (b) Available calcium hydroxide (rapid sugar test, ASTM C 25) plus total MgO content calculated to be equivalent Ca (OH)<sub>2</sub> min. percent ..... 30
- (c) As received loss on ignition (carbon dioxide plus moisture, Combined and free), max. percent ..... 40
- (d) Free Water (as received basis) max. percent ..... 4
- (e) Residue - The sieve analysis of the by product lime shall be as follows:

<u>Sieve</u>	<u>Maximum Percent Retained</u>
4.75 mm (No. 4)	5
600 µm (No. 30)	10
150 µm (No. 100)	25

**1012.04 By-Product Lime for Lime Stabilized Soil Mixture.** When used in lime stabilized soil mixture, hydrated or non-hydrated by-product lime shall meet the following requirements:

- (a) Total calcium oxides (nonvolatile basis) min. percent ..... 65
- (b) Available calcium hydroxide (rapid sugar test, as determined by ASTM C 25), min. percent ..... 35
- (c) Loss on ignition (carbon dioxide plus moisture, combined and free on as-received basis), max. percent ..... 35
- (d) Free Water (as received basis) max. percent ..... 2
- (e) Residue - The sieve analysis of the lime residue shall be as follows:

<u>Sieve</u>	<u>Maximum Percent Retained</u>
4.75 mm (No. 4)	5
600 µm (No. 30)	10
150 µm (No. 100)	25

**SECTION 1013. CHLORIDES**

**1013.01 Calcium Chloride.** Calcium chloride shall conform to the requirements of AASHTO M 144.

**1013.02 Sodium Chloride.** Sodium chloride shall conform to the requirements of AASHTO M 143, Type 1, Grade 1, except that the sodium chloride (NaCl) content shall be a minimum of 96.0 percent.

**SECTION 1014. MICROSILICA**

**1014.01 Description.** Microsilica is an amorphous silica of high silica content and purity possessing high pozzolanic activity.

**1014.02 Portland Cement Concrete.** The microsilica shall meet the standard physical and chemical requirements of AASHTO M 307, except that the Strength Activity Index requirement shall not apply. The microsilica shall meet the “Accelerated Pozzolanic Activity Index with Portland Cement” (at 7 days), according to ASTM C 1240. A limitation of available alkalis, as Na<sub>2</sub>O, of 1.5 percent, shall apply to microsilica used in portland cement concrete mixtures containing alkali-sensitive aggregates or admixtures. The Department’s Policy Memorandum, “Acceptance Procedure for Finely Divided Minerals Used In Portland Cement Concrete and Other Applications,” will be used to approve microsilica.

The microsilica shall be supplied either in a dry, densified form or as a water-based slurry.

Different sources of Microsilica shall not be mixed or used alternately in the same item of construction unless approved by the Engineer.

## **SECTION 1015. HIGH-REACTIVITY METAKAOLIN (HRM)**

**1015.01 Description.** High-Reactivity Metakaolin (HRM) is a reactive aluminosilicate pozzolan formed by calcining purified kaolinate at a specific temperature range.

**1015.02 Portland Cement Concrete.** The HRM shall meet the standard physical and chemical requirements of AASHTO M 295, for Mineral Admixture Class N, except that the Strength Activity Index requirement shall not apply. The HRM shall meet the "Accelerated Pozzolan Activity Index with Portland Cement" (at 7 days), according to ASTM C 1240. A limitation of available alkalis, as  $\text{Na}_2\text{O}$ , of 1.5 percent, shall apply to HRM used in portland cement concrete mixtures containing alkali-sensitive aggregates or admixtures. The Department's Policy Memorandum, "Acceptance Procedure for Finely Divided Minerals Used In Portland Cement Concrete and Other Applications," will be used to approve HRM.

The HRM shall be supplied in a dry, undensified form.

Different sources of HRM shall not be mixed or used alternately in the same item of construction unless approved by the Engineer.

## **SECTION 1016. GROUND GRANULATED BLAST-FURNACE (GGBF) SLAG**

**1016.01 Description.** Ground granulated blast-furnace slag (GGBF Slag) shall consist of the glassy granular material formed when molten blast-furnace slag is rapidly chilled, and then finely ground.

**1016.02 Portland Cement Concrete.** The GGBF shall meet the standard physical and chemical requirements of AASHTO M 302, for Grade 100 or Grade 120 material. The Department's Policy Memorandum, "Acceptance Procedure for Finely Divided Minerals Used In Portland Cement Concrete and Other Applications," will be used to approve GGBF.

Different sources or grades of GGBF shall not be mixed or used alternately in the same item of construction unless approved by the Engineer.

## **PORTLAND CEMENT CONCRETE ITEMS**

### **SECTION 1020. PORTLAND CEMENT CONCRETE**

**1020.01 Description.** This item shall consist of the materials, proportioning, mixing, transporting, curing and protecting portland cement concrete.

**1020.02 Materials.** Materials shall meet the requirements of the following Articles of Section 1000 - Materials:

	Item	Article/Section
(a)	Portland Cement .....	1001
(b)	Water .....	1002
(c)	Fine Aggregate .....	1003.01 - 1003.02
(d)	Coarse Aggregate .....	1004.01 - 1004.02
(e)	Admixtures .....	1021
(f)	Fly Ash .....	1010.03
(g)	Membrane Curing Compound .....	1022.01
(h)	Burlap Curing Blankets .....	1022.02
(i)	Waterproof Paper Blankets .....	1022.03
(j)	White Polyethylene Sheeting .....	1022.04
(k)	Burlap-Polyethylene Blanket .....	1022.05
(l)	Straw .....	1081.06(a)(1)

**1020.03 Equipment.** Equipment shall meet the requirements of the following Articles of Section 1100 - Equipment:

	Item	Article/Section
(a)	Concrete Mixers .....	1103.01
(b)	Batching and Weighing Equipment .....	1103.02
(c)	Automatic and Semi-Automatic Batching Equipment.....	1103.03
(d)	Water Supply Equipment .....	1103.11
(e)	Membrane Curing Equipment .....	1101.09
(f)	Mobile Portland Cement Concrete Plants .....	1103.04

**1020.04 Concrete Classes and General Mix Design Criteria.** The classes of concrete shown in the following Table 1 identify the various mixtures by the general uses and mix design criteria. If the class of concrete for a specific item of construction is not specified, Class SI Concrete shall be used.

Special classifications may be made for the purpose of including the concrete for a particular use or location as a separate pay item in the contract. The concrete used in such cases shall conform to this section.

TABLE 1. CLASSES OF PORTLAND CEMENT CONCRETE AND MIX DESIGN CRITERIA					
Class of Concrete	Use	Specification Section Reference	Cement Factor kg/cu m		Max. Water/Cement Ratio kg/kg
			Min.	Max.	
BD	Bridge Deck	503	360		0.44
PC	Precast Concrete Structures	504	335	418	0.44
	Precast Concrete Piles	512			
	Precast Concrete Barrier Temporary Concrete Barrier	637 704	335	418	0.44
PS	Precast Prestressed Members	504	335	418	0.44
	Precast Prestressed Piles	512			
PV	PCC Pavement Base Course Base Course Widen. Driveway Pav't	420, 421 353 354 423	335(1) 360(2)		
PP	PCC Pavement Patching	442	Ty I Cem 385 Ty III Cem 365	Ty I Cem 445 Ty III Cem 425	
MS	Massive Structures (except Superstructures)	503	335(1) 360(2)		
SI	Structures (except Br. Deck) Gutter Pile Encasement Curb & Gutter Median Tower Foundations Pole Foundations Culverts Handrails Headwalls Paved Ditch Slope Wall Sidewalk Cast-In-Place Concrete Barrier Miscellaneous	503 606 512 606 606 837 836 540 503 542 606 511 424 637 611	335(1) 360(2)		
RR	PCC Railroad Crossing	422			
SC	Seal Coat Concrete	503	335 (1) 360 (2)		
SH	PCC Shoulders Shoulder Curb	483 662	280		0.50

(1) Central mixed.

(2) Truck mixed or shrink mixed.

TABLE 1. (CONT'D) CLASSES OF PORTLAND CEMENT CONCRETE AND MIX DESIGN CRITERIA								
Class of Concrete	Slump, Mm	Mix Design Compressive Strength, kPa			Mix Design Flexural Strength, kPa		Air Content, %	Coarse Aggregate Gradations Permitted
		Days			Days			
		3	14	28	3	14		
BD	50-100		Min.			Min.	5.0-8.0	CA-7, CA-11 or CA-14
			27,500			4650		
PC	25-75			Min.			5.0-8.0	CA-7, CA-11,
				31,000				
	25-75			Min.				CA-14 or
				27,500			5.0-8.0	CA-7 & CA-16
PS	25-75			Min.			5.0-8.0	CA-7, CA-11, CA-14 or
				34,500				CA-7 & CA-16
PV	20-40	Ty III Cem Min. 24,000	Min. 24,000		Ty III Cem Min. 4500	Min. 4500	5.0-8.0	CA-5 & CA-7
								CA-5 & CA-11, CA-7, CA-11 or CA-14
PP	100 Max.						4.0-7.0	CA-7, CA-11,
								CA-13, CA-14, or CA-16
MS	50-100		Min. 24,000			Min. 4500	5.0-8.0	CA-3 & CA-7, CA-3 & CA-11, CA-5 & CA-7, CA-5 & CA-11, CA-7 or CA-11
SI	50-100		Min. 24,000			Min. 4500	5.0-8.0	CA-7, CA-11
								or CA-14
RR	50-100						4.0-7.0	CA-7, CA-11 or CA-14
SC	75-125		Min. 24,000			Min. 4500	N/A	CA-3 & CA-7, CA-3 & CA-11, CA-5 & CA-7, CA-7 & CA-11, CA-7 or CA-11
SH	20-40		Min. 18,500			Min. 3500	5.0-8.0	CA-5 & CA-7, CA-5 & CA-11, CA-7, CA-11, or CA-14



**TABLE 1. CLASSES OF PORTLAND CEMENT CONCRETE AND MIX DESIGN CRITERIA**

Class Of Concrete	Use	Specification Section Reference	Cement Factor cwt/c.y.		Max. Water/Cement Ratio lb/lb
			Min.	Max.	
BD	Bridge Deck	503	6.05		0.44
PC	Precast Concrete Structures	504	5.65	7.05	0.44
	Precast Concrete Piles	512			
	Precast Concrete Barrier Temporary Concrete Barrier	637 704	5.65	7.05	0.44
PS	Precast Prestressed Members Precast Prestressed Piles	504 512	5.65	7.05	0.44
PV	PCC Pavement Base Course Base Course Widen. Driveway Pav't	420, 421 353 354 423	5.65 (1) 6.05 (2)		
PP	PCC Pavement Patching	442	Ty I Cem 6.50 Ty III Cem 6.20	Ty I Cem 7.50 Ty III Cem 7.20	
MS	Massive Structures (except Superstructures)	503	5.65 (1) 6.05 (2)		
SI	Structures (except Br. Deck) Gutter Curb & Gutter Median Tower Foundations Pole Foundations Culverts Handrails Headwalls Paved Ditch Slope Wall Sidewalk Cast-In-Place Concrete Barrier Miscellaneous	503 606 606 606 837 836 540 503 542 606 511 424 637 611	5.65 (1) 6.05 (2)		
RR	PCC Railroad Crossing	422			
SC	Seal Coat Concrete	503	5.65 (1) 6.05 (2)		
SH	PCC Shoulders Shoulder Curb	483 662	4.75		0.50

(1) Central mixed.

(2) Truck mixed or shrink mixed.

TABLE 1. (CONT'D) CLASSES OF PORTLAND CEMENT CONCRETE AND MIX DESIGN CRITERIA								
Class of Concrete	Slump, In.	Mix Design Compressive Strength, psi			Mix Design Flexural Strength, psi		Air Content, %	Coarse Aggregate Gradations Permitted
		Days			Days			
		3	14	28	3	14		
BD	2-4		Min. 4000			Min. 675	5.0-8.0	CA-7, CA-11 or CA-14
PC	1-3			Min. 4500			5.0-8.0	CA-7, CA-11, CA-14 or
	1-3			Min. 4000			5.0-8.0	CA-7 & CA-16
							5.0-8.0	CA-7, CA-11
PS	1-3			Min. 5000				CA-14 or CA-7 & CA-16
PV	3/4 - 1 1/2	Ty III Cem Min. 3500	Min. 3500		Ty III Cem Min. 650	Min. 650	5.0-8.0	CA-5 & CA-7, CA-5 & CA-11, CA-7, CA-11 or CA-14
PP	4 Max.						4.0-7.0	CA-7, CA-11, CA-13, CA-14, or CA-16
MS	2-4		Min. 3500			Min. 650	5.0-8.0	CA-3 & CA-7, CA-3 & CA-11, CA-5 & CA-7, CA-5 & CA-11, CA-7 or CA-11
SI	2-4		Min. 3500			Min. 650	5.0-8.0	CA-7, CA-11 or CA-14
RR	2-4						4.0-7.0	CA-7, CA-11 or CA-14
SC	3-5		Min. 3500			Min. 650	N/A	CA-3 & CA-7, CA-3 & CA-11, CA-5 & CA-7, CA-7 & CA-11, CA-7 or CA-11
SH	3/4 - 1 1/2		Min. 2700			Min. 500	5.0-8.0	CA-5 & CA-7, CA-5 & CA-11, CA-7, CA-11, or CA-14

**1020.05 Other Concrete Criteria.**

- (a) Proportioning. For Class PC and Class PS Concrete, it shall be the Contractor's responsibility to determine the proportions of the materials for the concrete and to exercise quality control with respect to the mixture so that each batch of concrete entering into the members will meet the criteria specified herein. Before the work begins, the Contractor shall secure the Engineer's approval of the proportions of materials he/she proposes to use in the concrete and shall identify each of the materials as to name, source, brand, type, etc.

For all other classes of concrete, the Engineer will determine the proportions of materials for the concrete. The Engineer will furnish to prospective bidders, upon request, the approximate proportions by mass (weight) necessary to produce concrete having the required workability and strength, using aggregates from any approved commercial source. This information is only for the convenience of the bidder.

The Engineer reserves the right to determine, as the work progresses and as aggregates are delivered to the site of the work, the proportions of cement, water and aggregates actually furnished which will produce workable plastic concrete meeting the criteria specified herein. The proportions will be determined according to the procedure established in the latest "Manual of Instructions for Design of Concrete Mixtures". In case the proportions determined by the Engineer and used on the work vary from the approximate proportions previously furnished, because of changes in sources or variations in materials or for any other reason considered sufficient by the Engineer, no additional compensation will be paid to the Contractor.

For Class SC Concrete and for any other class of concrete that is to be deposited under water, the cement factor of the concrete mix shall be increased over the cement factor of the mix design by ten percent and a high range water reducing admixture shall be added to increase the slump to 150 to 200 mm (6 to 8 in.).

- (b) Admixtures. Except as specified, the use of admixtures to increase the workability or to accelerate the hardening of the concrete will be permitted only when approved in writing by the Engineer.

When the atmosphere or concrete temperature is 18 °C (65 °F) or higher, a retarding admixture meeting the requirements of Article 1021.03 shall be used in the Class BD Concrete and pcc bridge deck overlays. The amount of retarding admixture to be used will be determined by the Engineer. The proportions of the ingredients of the concrete shall be the same as without the retarding admixture except that the amount of mixing water shall be reduced, as may be necessary, in order to maintain the consistency of the concrete as required. In addition, a high range water reducer meeting the requirements of Article 1021.03 shall be used in the Class BD Concrete. The amount of high range water reducer will be determined by the Engineer. Type 1 cement shall be used.

For Class PC and PS Concrete, a retarding admixture may be added to the concrete mixture when the concrete temperature is 18 °C (65° F) or higher. The Engineer may order or permit the use of a retarding or water-reducing admixture whenever the Engineer considers it appropriate.

At the Contractor's option, admixtures other than air entraining agents may be used for Class PP Concrete. Admixtures shall be those from the Department's Approved Admixtures List. When calcium chloride is used, it shall be in a solution conforming to that described in the "Manual of Instructions for Concrete Proportioning and Testing". When a water-reducing or retarding admixture is used, the cement content may be reduced by up to 18 kg/cu m (0.30 hundredweight/cu yd).

For all other classes of concrete, at the option of the Contractor, or when specified by the Engineer, a water reducing admixture or a retarding admixture may be used. The amount of water reducing admixture or retarding admixture permitted will be determined by the Engineer. The air-entraining admixture and other admixtures shall be added to the concrete separately, and shall be permitted to intermingle only after they have separately entered the concrete batch. The sequence, method, and equipment for adding the admixtures shall be approved by the Engineer. The water reducing admixture shall not delay the initial set of the concrete by more than one hour. Type 1 cement shall be used. When a water-reducing admixture is added, a reduction in cement content of up to 18 kg/cu m (0.30 hundredweight/cu yd), from the concrete designed for a specific slump without the admixture, will be permitted. When an approved high range water-reducer is used, a cement reduction of up to 36 kg/cu m (0.60 hundredweight/cu yd), from a specific water cement ratio without the admixture, will be permitted based on a 14 percent minimum water reduction. Cement factor below 280 kg/cu m (4.75 hundredweight/cu yd) for Class SH Concrete and below 320 kg/cu m (5.35 hundredweight/cu yd.) for the remaining classes will not be permitted.

The maximum slumps given in Table 1 may be increased to 175 mm (7 in.) when a high range water-reducing admixture is used for all classes of concrete except Class PV.

- (c) Fly Ash. At the Contractor's option, fly ash from approved sources may partially replace portland cement in concrete mixtures, for Class BD, PV, MS, SI, SC, and SH, except when blended cements are utilized or when high-early-strength is required.

Fly ash and all other materials proposed for portland cement concrete mix designs shall be furnished to the Engineer at least 60 days prior to the initiation of work. The Engineer may elect to waive the required mix designs if the proposed materials combination has been previously approved and has demonstrated satisfactory field performance.

If Class F fly ash is used, the amount of cement replaced shall not exceed 15 percent by mass (weight) and the replacement ratio (fly ash cement replaced) shall be a minimum of 1.5:1. If Class C fly ash is used, the

amount of cement replaced shall not exceed 20 percent by mass (weight), at a minimum replacement ratio of 1.25:1.

For bridge decks, parapets, pier and abutment caps, backwalls, wingwalls and the upper 750 mm (2.5 ft) of solid piers, the amount of cement replaced shall not exceed 15 percent by mass (weight) at a minimum replacement ratio of 1.5:1, regardless of the type of fly ash used.

Measurements of fly ash and cement will be rounded up to the nearest 2.5 kg (5 lb).

Strength requirements for fly ash compensated mixes shall be a minimum of 95 percent of the requirements shown in Table 1 of Article 1020.04.

Requirements for opening the pavement and/or structures to traffic and removal of falsework shall be as stated in Article 701.05 and 503.05. For fly ash compensated mixtures, at least 28 days shall elapse in the absence of strength tests.

Fly ash shall not be used in concrete mixtures after October 15 nor before April 1 unless the Contractor provides lab test data demonstrating 14 day strength no less than that obtained from the equivalent cement-only mix.

Fly ash with an R factor greater than 3.0 shall not be used in concrete which will be subjected to high sulfate concentrations in soil or water. High sulfate soils shall be those with concentrations of water soluble sulfate (as  $\text{SO}_4$ ) greater than 0.10 percent, and high sulfate waters shall be those with sulfate concentrations (as  $\text{SO}_4$ ) greater than 150 parts per million.

- (d) Class BD Concrete. The maximum mortar factor will be 0.83.
- (e) Class PS Concrete. The cement used in the mix shall be Type I or Type III portland cement.
- (f) Class PV Concrete. The following special criteria shall apply to Class PV:
  - (1) A slump above the maximum specified in Table 1 of Article 1020.04 may be used with the Engineer's approval, up to a maximum of 75 mm (3 in.), provided the mixture's water/cement ratio does not exceed 0.42.
  - (2) Small quantities of Class SI may be used with the Engineer's approval. A unit coarse aggregate according to Article 1004.02(d) and (f) and Table 1 of Article 1020.04 will be required.
  - (3) The mortar content of the first 8 cu m (10 cu yds) or two batches, whichever is the greater, that is to be placed adjacent to a previously constructed transverse construction joint, shall be increased by the addition of cement and fine aggregate at the rates of 30 and 70 kg/cu m (50 and 120 lb/cu yd), respectively.

- (4) Class SI Concrete may be used for the construction of driveway pavement provided the coarse aggregate contained in the mixture complies with the Department's freeze-thaw requirements for pavement.
- (g) Class PP Concrete. The following special criteria shall apply:
  - (1) Early Strength Patching Mixture. Either Type III high-early-strength portland cement, a rich mix of Type I portland cement, or a concrete mixture containing an approved accelerator shall be used. The concrete mix design will be based on obtaining a compressive strength of not less than 22,000 kPa (3200 psi) or a modulus of rupture of not less than 4,150 kPa (600 psi) at the age of two days.
  - (2) Special Patching Mixture. Special patching mixture shall consist of the approximate proportions of materials per cubic meter (cubic yard):

Coarse Aggregate	1020 kg (1720 lb)
Fine Aggregate	665 kg (1120 lb)
Cement	440 kg (735 lb)
Water	145 kg (242 lb)
	[145 L (29 gal)]
Accelerator	10 L (2 gal)
High Range Water Reducer	5-10 L (1-2 gal)
Air Content	4.0-6.0%

The coarse aggregate shall be CA 7, CA 11, CA 14, or CA 16. Type I portland cement shall be used. The accelerator may be an approved admixture or it may be a calcium chloride solution conforming to that described in the Department's "Manual of Instructions for Concrete Proportioning and Testing". The water/cement ratio shall be no greater than 0.38 after the admixtures are added. The dosage of high range water reducer will be adjusted dependent upon brand and upon whether Type E (water reducing) accelerator or Type C (nonwater reducing - this includes calcium chloride solution) accelerator is used. The final slump shall be not more than 150 mm (6 in.).

The accelerator and high range water reducer shall be added to the truck mixer at the job site. The accelerator shall be added to the mixture before the high range water reducer. The truck mixer shall be reversed to discharge position so that the concrete is moved to the rear of the drum with discharge imminent. The accelerator shall then be added by dispensing directly onto the concrete and mixed 40 revolutions. After the accelerator has been mixed, the truck mixer shall again be reversed and the high range water reducer added and mixed in the same manner as the accelerator.

The air content will be verified after the admixtures have been mixed into the concrete.

Since this mixture stiffens rapidly under high ambient temperature conditions, no more than 2.5 cu m (3 cu yd) should be batched per truck

unless the truck can be discharged. Retempering with water will not be permitted.

This special patching mixture is intended to permit patches to be constructed and opened the same day and as soon as the flexural strength reaches the requirements of Article 701.05(e)(2)c. It is intended for use under hot ambient conditions [greater than 27 °C (80 °F)] and will not perform as satisfactorily under cooler conditions. When the air temperature in the shade is between 13 °C and 27 °C (55 °F and 80 °F) the mixture may be modified to offset the effects of the cooler conditions by using CA 7 or CA 11 coarse aggregate to reduce water demand, by increasing the dosage rate of calcium chloride solution up to 23.8 L/cu m (4.8 gal/cu yd), and by heating the mixing water to bring the plastic concrete to 29 °C (85 °F) minimum temperature.

- (h) Class SI Concrete. When used as slipformed concrete, the slump shall be not less than 13 mm (1/2 in.) nor more than 30 mm (1 1/4 in.)
- (i) Class RR Concrete. The following special criteria shall apply:
  - (1) The concrete mix design will be based on obtaining a compressive strength of not less than 24,000 kPa (3500 psi) or a modulus of rupture of not less than 4,500 kPa (650 psi) before the concrete crossing is opened to railroad traffic.
  - (2) Early strength concrete, either Type III portland cement or a rich mix of Type I portland cement, shall be used.
  - (3) It may be necessary to increase the mixing time to two minutes for the rich mix.
  - (4) Calcium chloride not to exceed one percent of the mass (weight) of cement in the mix may be added.
  - (5) The Department reserves the right to select the method to be used in obtaining high early strength, and to make such specimens and tests of the concrete as may be deemed necessary.
- (j) Class SH Concrete. The following special criteria shall apply:
  - (1) The fine aggregate volume shall not exceed the coarse aggregate volume.
  - (2) The special criteria (1), (2), and (3) for Class PV shall also apply.

**1020.06 Water/Cement Ratio.** The water/cement ratio is determined on a mass (weight) basis. When a maximum water/cement ratio is specified, the water shall include wash water, mixing water, water in admixtures, free moisture in the aggregates, and water added at the jobsite. The quantity of water may be adjusted by the Engineer, within the limit specified, to meet slump requirements.

When fly ash, ground granulated blast furnace slag, or microsilica are used as part of the cement in a concrete mix, the water/cement ratio will be based on the total cementitious material contained in the mixture.

**1020.07 Slump.** The slump will be determined according to AASHTO T 119.

Slump tests will be made as required by the "Manual for Inspectors of Precast Prestressed Concrete Products" for Class PC and PS, and as required by the "Project Procedures Guide" for all other classes. If the measured slump falls outside the limits specified, a check test will be made. In the event of a second failure, the Engineer may refuse to permit the use of the batch of concrete represented. At the time of placement, the slump of the concrete discharged from the container shall conform to Articles 1020.04 and 1020.05.

The mixture shall contain no more water than is necessary to produce concrete which is workable and plastic. The amount of water used will be determined by the Engineer. Corrections shall be made for the amount of moisture contained in the aggregates and allowance shall be made for absorption of moisture by the aggregates during the period of mixing and handling. A uniform consistency shall be maintained continuously.

If it is found impossible to prepare concrete of the specified consistency without exceeding the maximum design water content, additional cement or a water reducing admixture shall be added at no additional cost to the Department.

Equipment for conducting slump tests shall be furnished by the Contractor for Class PC or PS and by the Engineer for all other classes.

**1020.08 Air Content.** The air content shall be according to Articles 1020.04 and 1020.05 and shall be determined according to the Illinois Modified AASHTO T 152 or AASHTO T 196. The air-entrainment shall be obtained either by the use of air-entraining portland cement or by the use of nonair-entraining portland cement with an approved air-entraining admixture added during the process of mixing the concrete.

If the air-entraining portland cement furnished should be found to produce concrete having an air content outside the limits specified, its use shall be discontinued immediately and the Contractor shall provide other air-entraining portland cement which will produce air contents within the specified limits, or the Contractor may blend nonair-entraining portland cement at the batch plant with the Engineer's approval.

If the air content obtained is above the specified maximum limit at the jobsite, the Contractor, with the Engineer's approval, may add to the truck mixer nonair-entraining portland cement in the proportion necessary to bring the air content within the specified limits, or the concrete may be further mixed, within the limits of time and revolutions specified, to reduce the air content. If the air content obtained is below the specified minimum limit, the Contractor may add to the concrete during the process of mixing, a sufficient quantity of an approved air-entraining admixture at the job site to bring the air content within the specified limits.



Air-entraining admixture shall be added to the concrete by means of a mechanically activated dispenser meeting the requirements of Article 1103.03(a)(4), and permitting visual determination of the quantity dispensed. The air-entraining admixture shall be introduced into the stream of mixing water, and the required amount shall be fully discharged before all the mixing water has entered the drum. The tank feeding the dispenser shall at all times contain an amount of air-entraining admixture sufficient for the next batch, and shall be provided with a device, approved by the Engineer, for indicating visually when the supply runs low. The amount to be used shall be determined and shall be varied during the progress of the work, on the basis of air content determinations made by the Engineer to obtain air contents of the concrete within the specified limits.

Air tests will be as required by the "Manual for Inspectors of Precast Prestressed Concrete Products" for Class PC and PS Concrete, and as required by the "Project Procedures Guide" for all other classes of concrete. Equipment for conducting air tests shall be furnished by the Contractor for Class PC and PS, and by the Engineer for all other classes.

**1020.09 Strength Tests.** The compressive strength shall be determined according to AASHTO T 22. The flexural strength shall be determined according to the Illinois Modified AASHTO T 177. Details for fabricating, handling, curing, and testing the specimens for the various classes shall be according to the following. All costs to the Contractor for materials, labor, and equipment furnished in connection with fabricating, handling, transporting, storing, curing, and testing concrete specimens as hereinafter specified shall be included in the unit prices bid for the respective portland cement concrete items, and no additional compensation will be allowed.

- (a) Class PC Concrete. The Contractor shall make, cure and test the concrete test specimens as directed by the Engineer. A minimum of four test cylinders shall be made for each seven units constructed in a day or a minimum of four specimens per day if less than seven units are constructed. The test specimens shall remain with the units they represent and shall be subject to the same curing as the units until the time of testing.

The number of test specimens should be sufficient for determining the specified concrete strengths accurately. If the supply of test cylinders becomes exhausted, cores for additional tests shall be taken from the units as directed by the Engineer.

- (b) Class PS Concrete. A minimum of six concrete test cylinders shall be made in approved molds furnished by the Contractor from the concrete used in each casting bed. The procedures for making, handling, curing and testing the test specimens shall be as outlined in the "Manual for Inspectors of Precast Prestressed Concrete Products".
- (c) All Other Classes of Concrete. The Engineer reserves the right to make compression and flexural strength tests of the concrete or to waive such tests when it is impractical to make them. The specimens shall be molded and cured according to AASHTO T 23. The number of test specimens made

and tested for the various portland cement concrete items shall be as outlined in the Department's "Project Procedures Guide".

The test specimens shall be made from concrete taken from the mixtures in actual use. The Contractor shall transport the specimens from the site of the work to the field laboratory or other location on the work designated by the Engineer. During transportation, the specimens shall be embedded in straw, burlap, or other acceptable material in a manner meeting with the approval of the Engineer to protect them from damage; care shall be taken to avoid impacts during hauling and handling. Testing equipment and forms for the specimens will be furnished by the Department. The Contractor shall furnish the concrete used in making test specimens; a suitable light truck for use in transporting specimens; materials necessary for proper transportation and curing; and labor incidental to the preparation, transportation, storage, curing and testing.

**1020.10 Handling, Measuring, and Batching Materials.** Aggregates shall be handled in a manner to prevent mixing with soil and other foreign material.

Aggregates shall be handled in a manner which produces a uniform gradation, before placement in the plant bins. Aggregates delivered to the plant in a nonuniform gradation condition shall be stockpiled. The stockpiled aggregate shall be mixed uniformly before placement in the plant bins.

Aggregates shall have a uniform moisture content before placement in the plant bins. This may require aggregates to be stockpiled for 12 hours or more to allow drainage, or water added to the stockpile, or other methods approved by the Engineer. Moisture content requirements for crushed slag shall be according to Article 1004.01(e).

Aggregates, cement and cementitious materials shall be measured by mass (weight). A device shall indicate the complete discharge of the batch of cement or cementitious material. Water and admixtures shall be measured by volume or mass (weight).

The Engineer may permit aggregates, cement, and cementitious materials to be measured by volume for small isolated structures, and for miscellaneous items. Aggregates, cement, and cementitious materials shall be measured individually. The volume shall be based upon dry, loose materials.

A plant shall be equipped to batch materials manually, semi-automatically, or automatically, according to Section 1103.

**1020.11 Mixing Portland Cement Concrete.** The mixing requirements vary somewhat, depending on the class of concrete and its specific use. Two types of concrete are used - jobsite mixed or ready-mixed. Jobsite-mixed concrete is mixed in a stationary mixer and transported to the place of deposit in an agitating or nonagitating truck. Ready-mixed concrete may be mixed in a stationary mixer at the ready-mix plant and transported to the jobsite in agitating or nonagitating trucks or it may be batched at the ready-mix plant and mixed and hauled to the jobsite in truck mixers.

The specific mixing requirements for the various classes of concrete are as follows:

- (a) Class PC Concrete. Class PC Concrete shall be mixed in a jobsite mix plant or may be obtained from a ready-mix plant.

If a jobsite mix plant is used, the mixer and batching equipment shall conform to Article 1103.01(a) and 1103.02, shall be an integral part of the plant equipment, and shall be approved by the Engineer. Mixing in the stationary mixer shall conform to the requirements in Article 1020.11(c), except that the mixing time, after all materials except water are in the drum, shall be not less than one minute for mixers having a capacity of 1.5 cu m (2 cu yd) or less. A truck mixer may be used provided it meets the requirements specified for Class PS Concrete in (b) below.

If ready-mixed concrete is used, the ready-mix plant furnishing the concrete shall be certified under the latest NRMCA certification of Ready-Mix Concrete Production Facilities and shall produce the specified concrete mixture. Each ready-mix plant shall furnish the Engineer a copy of the certification which shall be good for two years after certification.

- (b) Class PS Concrete. Class PS Concrete shall be mixed in a jobsite mix plant that is an integral part of the prestressing plant as specified above in Article 1020.11(a).

If approved in writing by the Engineer, a truck mixer and batching plant that are an integral part of the prestressing plant equipment may be used provided the mixing conforms to the requirements of Article 1020.11(d) and to the following:

- (1) Measurements and addition of mixing water shall comply with the requirements of Article 1020.11(d), except all wash water shall be completely discharged from the drum or container before the succeeding batch is placed.
- (2) The truck mixer shall be capable of discharging concrete with a slump of 50 mm (2 in.).
- (3) Truck mixers which do not obtain complete and uniform mixing of the batch materials and which have variations in slump greater than 20 mm (3/4 in.) within or between batches will be rejected until such time as they have been repaired and approved for mechanical condition.
- (4) Batching facilities and procedures that do not provide satisfactorily mixed concrete will not be permitted.

Concrete from a ready-mix plant will not be permitted for use in Class PS Concrete construction except to complete the casting of a beam in the case of a breakdown in concrete-supplying equipment. The ready-mix plant furnishing the concrete shall be certified under the latest NRMCA certification of Ready-Mix Concrete Production Facilities and the mixture furnished shall be that specified for the beam. Each ready-mix plant shall

furnish the Engineer a copy of the certification which shall be good for two years after certification.

- (c) Class PV and SH Concrete shall be mixed in a stationary mixer or truck mixer, according to Article 1103.01(a) and (b). Truck-mixed concrete shall be produced according to Article 1020.11(d). The stationary mixer shall be at an approved location and used exclusively for work subject to inspection by the Engineer. The plastic concrete shall be hauled to the construction site in agitator or nonagitator trucks conforming to Article 1103.01(c) and (d).

The stationary mixer shall operate at the drum speed for which it was designed. The batch shall be charged into the drum so that some of the water shall enter in advance of the cement and aggregates. The flow of the water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period. As an objective, water should begin to enter the drum from zero to two seconds in advance of solid material and should stop flowing within two seconds of the beginning of mixing time.

Some coarse aggregate shall enter in advance of other solid materials. For the balance of the charging time for solid materials, the aggregates and cement (to assure thorough blending) shall each flow at acceptably uniform rates, as determined by visual observation. Coarse aggregate should enter two seconds in advance of other solid materials and a uniform rate of flow should continue to within two seconds of the completion of charging time.

The entire contents of the drum, or of each single compartment of a multiple-drum mixer, shall be discharged before the succeeding batch is introduced.

The volume of concrete mixed per batch shall not exceed by more than ten percent the mixer's rated capacity as shown on the standard rating plate on the mixer.

The minimum mixing time shall be 75 seconds for a stationary mixer. Transfer time in multiple drum mixers is included in the mixing time. Mixing time shall begin when all solid materials are in the mixing compartment and shall end when the discharge of any part of the batch is started. The required mixing times will be established by the Engineer for all types of stationary mixers.

The required mixing time for stationary mixers may be less than 75 seconds upon satisfactory completion of a mixer performance test. Mixer performance tests may be requested by the Contractor when the quantity of concrete to be placed exceeds 42,000 sq m (50,000 sq yd). The tests will be conducted according to the standard methods adopted by the Department.

The Contractor will be allowed to test two mixing times within a range of 50 to 75 seconds. If satisfactory results are not obtained from the required tests, the mixing time shall continue to be 75 seconds for the remainder of the contract. If satisfactory results are obtained, the acceptable mixing time may be reduced for those particular circumstances to the mixing time which

test results indicate to provide satisfactory mixing. In no event will mixing time be less than 50 seconds.

No additional compensation will be allowed the Contractor for any delays or inconveniences if the Contractor elects to change the mixing time. The Contractor shall furnish the labor, equipment, and material required by the Engineer to make the tests listed above with the cost being included in the unit bid prices for the various items of portland cement concrete involved.

When mixer performance tests have been successfully completed and a reduced mixing time has been established, the Contractor may request, in writing, permission to operate this same plant and mixer setup on other pavement or base course contracts at the reduced established mixing time. Approval by the Engineer will depend upon past performance. If, in the Engineer's opinion, conditions have changed so as to affect the quality of concrete, the Engineer may require additional tests.

A contract which has 3.6 m (12 ft) wide pavement or base course, and a continuous length of 0.8 km (1/2 mile) or more, shall have the following additional requirements:

- (1) The plant and truck delivery operation shall be able to provide a minimum of 38 cu m (50 cu yd) of concrete per hour.
  - (2) The truck mixer shall discharge all wash water prior to batching the concrete materials.
  - (3) The plant shall have automatic or semi-automatic batching equipment, according to Article 1103.03.
- (d) All Other Classes of Concrete. The concrete shall be mixed at the site of work only in the quantities required for immediate use or ready-mixed concrete shall be used.

When the concrete is mixed at the site of the work, a stationary mixer conforming to Article 1103.01(a) shall be used and the mixing shall be performed according to Article 1020.11(c) except that the minimum mixing time shall be one minute for mixers having a capacity of 1.5 cu m (2 cu yd) or less.

When ready-mixed concrete is used, it shall be transported to the work in truck mixers, truck agitators or nonagitating trucks having special bodies. Ready-mixed concrete is a central-mixed, truck-mixed, or shrink-mixed concrete meeting the following requirements:

- (1) Central-Mixed Concrete. Central mixed concrete is concrete which has been completely mixed in a stationary mixing plant approved by the Engineer.

The mixer shall be rotated at the rate recommended by its manufacturer. The mixing time shall be measured from the time that all cement and aggregates are in the mixer. The batch shall be charged

into the drum so that some water shall enter in advance of the aggregates. The flow of the water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period. When the stationary mixing plant is used for the complete mixing of the concrete to be transported as wet batches, the mixing time for mixers having a capacity of 1.5 cu m (2 cu yd) or less shall be not less than one minute; for mixers of larger capacity, this minimum mixing time shall be 75 seconds.

The vehicles used for transporting the mixed concrete shall be of such capacity, or the batches shall be so proportioned, that the entire contents of the mixer drum can be discharged into each vehicle load.

- (2) **Truck-Mixed Concrete.** Truck-mixed concrete is completely mixed in a truck mixer. When the mixer is charged with fine and coarse aggregates simultaneously, not less than 60 nor more than 100 revolutions of the drum or blades at mixing speed shall be required, after all of the ingredients including water are in the drum. When fine and coarse aggregates are charged separately, not less than 70 revolutions will be required. Additional mixing beyond 100 revolutions shall be at agitating speed unless additions of water and/or admixtures are made at the direction of the Engineer. The mixing operation shall begin immediately after the cement and water, or the cement and wet aggregates, come in contact. The ingredients of the batch shall be completely discharged from the drum before the succeeding batch is introduced. Drums and auxiliary parts of the equipment shall be kept free from accumulations of materials. If additional water or an admixture is added at the jobsite, the concrete batch shall be mixed a minimum of 40 additional revolutions after each addition.
- (3) **Shrink-Mixed Concrete.** Shrink-mixed concrete is mixed partially in a stationary mixer and completed in a truck mixer. The mixing time at the stationary mixing plant may be reduced to a minimum of 30 seconds to intermingle the ingredients, before transferring to the truck mixer. All ingredients for the batch shall be in the stationary mixer and partially mixed before any of the mixture is discharged into the truck mixer. The partially mixed batch shall be transferred to the truck mixer without delay and without loss of any portion of the batch, and mixing in the truck mixer shall start immediately. The mixing time in the truck mixer shall be not less than 50 nor more than 100 revolutions of the drum or blades at mixing speed. Units designed as agitators shall not be used for shrink mixing. Except for the preceding requirements, shrink mixing shall conform to the requirements in (2) for truck-mixed concrete.
- (4) **Agitating.** Agitating is the process of continuing the mixing of concrete in a truck mixer or agitator for the purpose of preventing segregation while in transit to the destination.

When central-mixed concrete is to be transported in a truck agitator or a truck mixer, the stationary-mixed batch shall be transferred to the agitating unit without delay and without loss of any portion of the batch. Agitating shall start immediately thereafter and shall continue without

interruption until the batch is discharged from the agitator. The ingredients of the batch shall be completely discharged from the agitator before the succeeding batch is introduced. Drums and auxiliary parts of the equipment shall be kept free from accumulations of materials.

- (5) **Mixing Water.** No additional water may be added at the jobsite to central-mixed concrete if a reduction in the cement factor has been given for central-mixed concrete. All mixing water shall be added at the batch plant and no water may be added at the jobsite to exceed the design slump.

Washing water, if used, shall be either completely discharged from the drum or container before the succeeding batch is introduced, or if permitted by the Engineer, remain as a portion of the mixing water for the succeeding batch, and shall be accurately measured and taken into account in determining the amount of additional mixing water required.

- (6) **Mixing and Agitating Speeds.** The mixing speed for the revolving drum type of truck mixer shall be the manufacturer's recommended speed as displayed on the rating plate. If the concrete is inadequately mixed, the mixing speed shall be not less than five revolutions per minute of the drum, nor greater than a speed resulting in a peripheral velocity of the drum of 69 m (225 ft)/min. For the revolving blade type of mixer, the mixing speed shall be not less than five nor more than 16 revolutions per minute of the mixing blades.

Agitating speed, for both the revolving drum and revolving blade types, shall be not less than two nor more than five revolutions per minute of the drum or of the mixing blades.

Truck mixer blades at the point of maximum drum diameter, nearest to the drum head, shall not be worn more than ten percent of the original radial height. The Engineer will determine the original radial height from the blade dimensions provided by the manufacturer, or other available information.

- (7) **Capacities.** The volume of plastic concrete in a given batch will be determined according to AASHTO T 121, based on the total mass (weight) of the batch, determined either from the masses (weight) of all materials, including water, entering the batch or directly from the net mass (weight) of the concrete in the batch as delivered.

The volume of mixed concrete in truck mixers or truck agitators shall in no case be greater than the rated capacity determined according to the Truck Mixer, Agitator, and Front Discharge Concrete Carrier Standards of the Truck Mixer Manufacturer's Bureau, as shown by the rating plate attached to the truck. If the truck mixer does not have a rating plate, the volume of mixed concrete shall not exceed 63 percent of the gross volume of the drum or container, disregarding the blades. For truck agitators, the value is 80 percent.

For the purpose of determining the gross volume of the container of the revolving blade type of truck mixer or agitator, the height of the container above the center shaft will be considered no greater than the radius of the circular section of the container below the center shaft, and the overall width will be considered no greater than the diameter of the circular section.

- (8) Time of Haul. Haul time shall begin when the delivery ticket is stamped. The delivery ticket shall be stamped no later than five minutes after the addition of the mixing water to the cement and aggregates, or after the addition of the cement to the aggregate when the mixer drum contains residual water or the combined aggregates contain free moisture in excess of two percent by mass (weight). Haul time shall end when the truck is emptied for incorporation of the concrete into the work. For concrete mixed in jobsite stationary mixers, the stamped delivery ticket may be waived, but a method of verifying the haul time shall be established to the satisfaction of the Engineer.

The time elapsing from when water is added to the mix until it is deposited in place at the site of the work shall not exceed 30 minutes when the concrete is transported in nonagitating trucks.

Concrete transported in truck mixers or truck agitators shall be delivered to the site of the work in a plastic and workable condition, satisfactory for placement in the work without the addition of water or water and cement prior to discharging.

The maximum haul time for concrete transported in truck mixers or truck agitators shall be according to the following:

Concrete Temperature		Haul Time	
at Point of Discharge	°C ( °F)	Hours	Minutes
10-17.5	(50-64)	1	30
18-32	(65-90)	1	0
			(without retarder)
18-32	(65-90)	1	30
			(with retarder)

To encourage start-up testing for mix adjustments at the plant, the first two trucks will be allowed an additional 15 minutes haul time whenever such testing is performed.

The producer of ready-mixed concrete shall furnish proof of compliance with the above requirements with each delivery of concrete in the form of a ticket stamped by an approved time clock. Each ticket shall be delivered to the Engineer or his/her representative upon arrival on the job.

- (9) Production and Delivery. The production of ready-mixed concrete shall be such that the operations of placing and finishing will be continuous insofar as the job operations require. The Contractor shall be responsible for producing concrete that will have the required



consistency when delivered to the work. Concrete which is unsuitable for placement as delivered will be rejected.

The Engineer may require such modification of procedures as will produce satisfactory results. If it proves impracticable to complete the work before the concrete becomes too stiff to finish properly, the Engineer may order the discontinuance of the use of ready-mixed concrete.

**1020.12 Mobile Portland Cement Concrete Plants.** The use of a mobile portland cement concrete plant may be approved under the provisions of Article 1020.10 for volumetric proportioning in small isolated structures, thin overlays, and for miscellaneous and incidental concrete items.

The first 0.03 cu m (1cu ft) of concrete produced may not contain sufficient mortar and shall not be incorporated in the work. The side plate on the cement feeder shall be removed periodically (normally the first time the mixer is used each day) to see if cement is building up on the feed drum.

Sufficient mixing capacity of mixers shall be provided to enable continuous placing and finishing insofar as the job operations and the Specifications require.

Slump and air tests made immediately after discharge of the mix may be misleading, since the aggregates may absorb a significant amount of water for four or five minutes after mixing.

**1020.13 Curing and Protection.** The methods of curing and protection and the length of the curing period vary somewhat, depending on the type of construction involved. A ready reference for the method of curing, curing period, and method of protection for each of the various types of concrete construction is included in the following Index Table.

INDEX TABLE OF CURING AND PROTECTION OF CONCRETE CONSTRUCTION			
TYPE OF CONSTRUCTION	CURING METHODS	CURING PERIOD DAYS	PROTECTION METHODS
Pavement	1020.13(a)(1)(2)(3)(4) <sup>3/6/</sup>	3	1020.13(c)
Base Course	1020.13(a)(1)(2)(3)(4) <sup>1/2/</sup>	3	1020.13(c)
Base Course Widening	1020.13(a)(1)(2)(3)(4) <sup>1/2/</sup>	3	1020.13(c)
Driveways	1020.13(a)(1)(2)(3)(4) <sup>4/6/</sup>	3	1020.13(c)
Median	1020.13(a)(1)(2)(3)(4) <sup>4/6/</sup>	3	1020.13(c)
Concrete Gutter, Curb			
Combination Curb and Gutter	1020.13(a)(1)(2)(3)(4) <sup>4/6/</sup>	3	1020.13(c)
Sidewalk	1020.13(a)(1)(2)(3)(4) <sup>4/6/</sup>	3	1020.13(c)
Slope Wall	1020.13(a)(1)(2)(3)(4) <sup>4/6/</sup>	3	1020.13(c)
Paved Ditches	1020.13(a)(1)(2)(3)(4) <sup>4/</sup>	3	1020.13(c)
Catch Basin, Manhole, Inlet			
And Valve Vault	1020.13(a)(1)(2)(3)(4) <sup>4/</sup>	3	1020.13(c)
Pavement Patching	1020.13(a)(1)(2)(3)(4) <sup>2/</sup>	3 <sup>7/</sup>	1020.13(c)
Pavement Replacement	1020.13(a)(1)(2)(3)(4) <sup>1/2/</sup>	3	1020.13(c)
Railroad Crossing	1020.13(a)(3)	1	1020.13
Piling5/	1020.13(a)(3)	7	1020.13(e)(1)(2)(3)
Footings, Foundations	1020.13(d), 1020.13(a)(1)(2)(3)(4) <sup>4/</sup>	7	1020.13(e)(1)(2)(3)
Substructure	1020.13(d)(2) <sup>1/</sup>	7	1020.13(e)(1)(2)(3)
Superstructure (except deck)	1020.13(a)(1)(2)(3)	7	1020.13(e)(1)(2)
Deck	1020.13(a)(3)	7	1020.13(e)(1)(2)
Retaining Walls	1020.13(d)(2) <sup>1/</sup>	7	1020.13(e)(1)(2)
Pump House	1020.13(d)(2) <sup>1/</sup>	7	1020.13(e)(1)(2)
Culverts and Headwalls	1020.13(d)(2) <sup>4/</sup>	7	1020.13(e)(1)(2)
Other Incidental Concrete	1020.13(a)(1)(2)(3)	3	1020.13(c)
Precast Concrete Members	See Section 504		

Notes-General:

- 1/ Type I, membrane curing only
- 2/ Type II, membrane curing only
- 3/ Type III, membrane curing only
- 4/ Type I, II and III membrane curing
- 5/ See Section 512 for additional requirements
- 6/ Membrane Curing will not be permitted between November 1 and April 15.
- 7/ Curing maintained only until opening strength is attained, with a maximum curing period of three days.

- (a) Methods of Curing. Except as provided for in the above Table, curing shall be accomplished by one of the following described methods. When water is required to wet the surface, it shall be applied as a fine spray so that it will not mar or pond on the surface. Except where otherwise specified, the curing period shall be at least 72 hours. If high-early-strength portland cement is permitted, the curing period may be reduced as directed by the Engineer.

- (1) Waterproof Paper Method. The surface of the concrete shall be covered with waterproof paper as soon as the concrete has hardened sufficiently to prevent marring the surface. The surface of the concrete shall be wetted immediately before the paper is placed. The blankets shall be lapped at least 300 mm (12 in.) end to end, and these laps shall be securely weighted with a windrow of earth, or other approved method, to form a closed joint. The same requirements shall apply to the longitudinal laps where separate strips are used for curing edges, except the lap shall be at least 225 mm (9 in.). The edges of the blanket shall be weighted securely with a continuous windrow of earth or any other means satisfactory to the Engineer to provide an air-tight cover. Any torn places or holes in the paper shall be repaired immediately by patches cemented over the openings, using a bituminous cement having a melting point of not less than 82 °C (180 °F). The blankets may be reused, provided they are air-tight and kept serviceable by proper repairs.

A longitudinal pleat shall be provided in the blanket to permit shrinkage where the width of the blanket is sufficient to cover the entire surface. The pleat will not be required where separate strips are used for the edges. Joints in the blanket shall be sewed or cemented together in such a manner that they will not separate during use.

The Engineer may approve the use of other impermeable covering, in lieu of waterproof paper, provided it has been shown through laboratory and field investigation that the results obtained are at least as satisfactory as those obtained with waterproof paper.

- (2) Polyethylene Sheeting Method. The surface of the concrete shall be covered with white polyethylene sheeting as soon as the concrete has hardened sufficiently to prevent marring the surface. The surface of the concrete shall be wetted immediately before the sheeting is placed. The edges of the sheeting shall be weighted securely with a continuous windrow of earth or any other means satisfactory to the Engineer to provide an air-tight cover. Adjoining sheets shall overlap not less than 300 mm (12 in.) and the laps shall be securely weighted with earth, or any other means satisfactory to the Engineer, to provide an air tight cover. For portland cement concrete surface and base course, the polyethylene sheets shall be not less than 30 m (100 ft) in length nor longer than can be conveniently handled, and shall be of such

width that, when in place, they will cover the full width of the surface, including the edges, except that separate strips may be used to cover the edges. Any torn places or holes in the sheeting shall be repaired by cemented patches. When sheets are no longer serviceable as a single unit, the Contractor may select from such sheets and reuse those which will serve for further applications, provided two sheets are used as a single unit; however, the double sheet units may be rejected when the Engineer deems that they no longer provide an air tight cover.

- (3) Wetted Burlap Method. The surface of the concrete shall be covered with wetted burlap blankets as soon as the concrete has hardened sufficiently to prevent marring the surface. The blankets shall overlap 150 mm (6 in.). At least two layers of wetted burlap shall be placed on the finished surface. The burlap shall be kept saturated by means of a mechanically operated sprinkling system. In place of the sprinkling system, at the Contractor's option, two layers of burlap covered with impermeable covering shall be used. The burlap shall be kept saturated with water. Plastic coated burlap may be substituted for one layer of burlap and impermeable covering.

The blankets shall be placed so that they are in contact with the edges of the concrete, and that portion of the material in contact with the edges shall be kept saturated with water.

- (4) Membrane Curing Method. Membrane curing will not be permitted where a protective coat or waterproofing is to be applied or at areas where rubbing or a normal finish is required or at construction joints other than those necessary in pavement or base course. Concrete at these locations shall be cured by another method specified in this Section at no additional cost to the Department.

After the concrete has been finished and immediately after the water sheen has disappeared from the surface of the concrete, the surface shall be sealed with membrane curing compound of the type specified. The seal shall be maintained for the specified curing period. The edges of the concrete shall, likewise, be sealed immediately after the forms are removed. Two separate applications, applied at least one minute apart, each at the rate of not less than 0.16 L/sq m (1 gal/250 sq ft) will be required upon the surfaces and edges of the concrete. These applications shall be made with the mechanical equipment specified. Type III compound shall be agitated immediately before and during the application.

At locations where the coating is discontinuous or where pin holes show or where the coating is damaged due to any cause and on areas adjacent to sawed joints, immediately after sawing is completed, an additional coating of membrane curing compound shall be applied at the above specified rate. The equipment used may be of the same type as that used for coating variable widths of pavement. Before the additional coating is applied adjacent to

sawed joints, the cut faces of the joint shall be protected by inserting a suitable flexible material in the joint, or placing an adhesive width of impermeable material over the joint, or by placing the permanent sealing compound in the joint. Material, other than the permanent sealing compound, used to protect cut faces of the joint, shall remain in place for the duration of the curing period. In lieu of applying the additional coating, the area of the sawed joint may be cured according to any other method permitted.

If rain occurs before an application of membrane curing compound has dried, and the coating is damaged, another application shall be made in the same manner and at the same rate as the original coat. No additional compensation will be allowed the Contractor for materials or labor required to perform this work. The Engineer may order curing by another method specified, if unsatisfactory results are obtained with membrane curing compound; therefore, prior to starting paving, the Contractor shall have available, at the site of the work, a supply of one of the other approved curing materials sufficient to cover one day's production.

- (b) Removing and Replacing Curing Covering. When curing methods specified above in Article 1020.13(a), (1), (2) or (3) are used for portland cement concrete pavement, the curing covering for each day's paving shall be removed to permit testing of the pavement surface with a profilograph or straightedge, as directed by the Engineer.

Immediately after testing, the surface of the pavement shall be wetted thoroughly and the curing coverings replaced. The top surface and the edges of the concrete shall not be left unprotected for a period of more than 1/2 hour.

- (c) Protection of Portland Cement Concrete, Other Than Structures, From Low Temperatures. When the official National Weather Bureau Forecast for the construction area predicts a low of 0 °C (32 °F), or lower, or if the actual temperature drops to 0 °C (32 °F), or lower, concrete less than 72 hours old shall be provided at least the following protection:

Minimum Temperature	Protection
-4 °C - 0 °C (25 °F-32 °F)	two layers of polyethylene sheeting or one layer of polyethylene and one layer of burlap, or two layers of waterproof paper.
Below -4 °C (25 °F)	150 mm (6 in.) of straw covered with one layer of polyethylene sheeting or waterproof paper.

These protective covers shall remain in place until the concrete is at least 96 hours old. When straw is required on pavement cured with membrane curing compound, the compound shall be covered with a layer of burlap, polyethylene sheeting or waterproof paper before the straw is applied.

After September 15, there shall be available to the work within four hours, sufficient clean, dry straw to cover at least two days production of the mixer. Additional straw shall be provided as needed to afford the protection required. Regardless of the precautions taken, the Contractor shall be responsible for protection of the concrete placed and any concrete damaged by cold temperatures shall be removed and replaced by the Contractor at his/her own expense.

- (d) Curing of Structures. In constructing grade separation structures, pump houses, retaining walls, bridges, and culverts, all concrete shall be cured for not less than seven days nor more than ten days after the concrete has been placed. Form removal may be allowed if continued curing procedures are implemented within two hours from the time of the start of the form removal.

When waterproofing is specified and when permitted according to Article 503.18, Asphalt Emulsion for Waterproofing may be used in lieu of other curing methods.

- (1) Curing Structure Footings and Foundations. Concrete may be cured by any of the methods listed under Article 1020.13(a). The use of water to inundate footings and foundations is permissible when approved by the Engineer, provided the water temperature can be maintained at 7 °C (45 °F) or higher. Material and insulation used for curing or protection of the concrete may be removed the following day in areas where the Contractor must place forms to construct the successive pours of concrete.
- (2) Substructure Concrete. Forms on substructure units shall remain in place at least 24 hours after which the Contractor may remove forms according to Article 503.06 providing the remainder of the curing period is met by the use of one of the curing methods permitted under Article 1020.13(a).
- (3) Bridge Floors. The top surface of bridge floors placed between October 15 and April 15 of the following year shall be cured according to Article 1020.13(a)(3). Protective coat shall be applied to these floors according to Article 503.19.

The top surface of bridge floors placed between April 15 and October 15 of the same year shall be sprayed according to Article 1020.13(a)(4) and as specified with a Type II membrane curing compound immediately after the texturing operation is completed. As soon as the membrane curing compound has dried, the top

surface shall then be immediately cured according to Article 1020.13(a)(3). Protective coat shall not be applied to these floors.

- (4) Superstructure (Except Bridge Floors). Concrete may be cured by Methods (1), (2) or (3) under Article 1020.13(a). On non traffic surfaces which receive a normal finish, a linseed oil emulsion curing compound meeting the requirements of Article 1022.01(a) will be permitted provided it is applied with a mechanical sprayer meeting the requirements of Article 1101.09(b).
- (e) Protection of Structures From Low Temperatures. If temperatures below 7 °C (45 °F) are forecast, protection methods will be required. Concrete shall not be placed when the air temperature is below 7 °C (45 °F) and falling or below 4 °C (40 °F) without permission of the Engineer. The temperature of plastic concrete shall be according to Article 1020.14(b) at the time of placement. All exposed surfaces within the housing shall be cured according to the Index Table.

The Contractor shall provide means for checking the temperature of the surface of the concrete or air temperature within the housing during the protection period.

In constructing grade separation structures, pump houses, retaining walls, bridges and culverts having a waterway opening of more than 1 sq m (10 sq ft), if the concrete is placed between December 1 and March 15 (winter period), the concrete shall be protected by Protection Method I or Protection Method II. In the construction of all structures not specified and all incidental construction including footings and slope walls, concrete may be protected by Protection Method III. Concrete shall not be placed until the protection and facilities are approved by the Engineer.

The Contractor may be required to place concrete in the structures specified above during the winter period, when directed by the Engineer. If winter construction is specified, the Contractor shall proceed with the construction of these structures, including concrete, excavation, pile driving, steel erection, and all appurtenant work required for the complete construction of the structures during the winter period, except at times when weather conditions make such operations impracticable.

If the concrete is placed outside the winter period, and the temperature is below 7 °C (45 °F) or at any time during the first three days falls below 7 °C (45 °F), the concrete shall be protected according to Protection Method I or Protection Method II. In the construction of all structures not specified and all incidental construction, including footings and slope walls, concrete may be protected by Protection Method III. When Protection Method II is used to protect the concrete in bridge decks, the housing may enclose only the bottom and sides. The top surface shall be protected by Protection Method I.

- (1) Protection Method I. The concrete shall be completely covered with insulating material such as fiberglass, rock wool, or other approved commercial insulating material having the minimum thermal resistance R, as defined in ASTM C 168, for the corresponding minimum dimension of the concrete unit being protected as shown in the following table:

Minimum Pour Dimension mm	(in.)	Thermal Resistance R
150 or less	(6 or less)	R=16
>150 to 300	(>6 to 12)	R=10
>300 to 450	(>12 to 18)	R=6
450	(>over 18)	R=4

The insulating material manufacturer shall clearly mark the insulating material with the thermal resistance R value.

The insulating material shall be completely enclosed on sides and edges with an approved waterproof liner and shall be maintained in a serviceable condition. Any tears in the liner shall be repaired in a manner approved by the Engineer.

On formed surfaces, the insulating material shall be attached to the outside of the forms with wood cleats or other suitable means to prevent any circulation of air under the insulation and shall be in place before the concrete is placed. The blanket insulation shall be applied tightly against the forms. The edges and ends shall be attached so as to exclude air and moisture. If the blankets are provided with nailing flanges, the flanges shall be attached to the studs with cleats. Where tie rods or reinforcement bars protrude, the areas adjacent to the rods or bars shall be adequately protected in a manner satisfactory to the Engineer. Where practicable, the insulation shall overlap any previously placed concrete by at least 300 mm (1 ft). Insulation on the underside of floors on steel members shall cover the top flanges of supporting members. On horizontal surfaces, the insulating material shall be placed as soon as the concrete has set so that the surface will not be marred and shall be covered with canvas or other waterproof covering. The insulating material shall remain in place for a period of seven days after the concrete is placed.

The Contractor may remove the forms providing the temperature is 2 °C (35 °F) and rising and the Contractor is able to wrap the particular section within two hours from the time of the start of the form removal. The insulation shall remain in place for the remainder of the seven days curing period.

- (2) Protection Method II. The concrete shall be enclosed in adequate housing and the air surrounding the concrete kept at a temperature of not less than 10 °C (50 °F) nor more than 27° C (80° F) for a



period of seven days after the concrete is placed. Concrete shall not be placed until the protection and facilities for heating have been approved by the Engineer. All exposed surfaces within the housing shall be cured according to the Index Table.

The Contractor shall provide adequate fire protection where heating is in progress and such protection shall be accessible at all times. The Contractor shall maintain labor to keep the heating equipment in continuous operation.

At the close of the heating period, the temperature shall be decreased to the approximate temperature of the outside air at a rate not to exceed 8 °C (15 °F) per 12 hour period, after which the housing may be removed. The surface of the concrete shall be permitted to dry during the cooling period.

- (3) Protection Method III. As soon as the surface is sufficiently set to prevent marring, the concrete shall be covered with 300 mm (12 in.) of loose, dry straw followed by a layer of impermeable covering. The edges of the covering shall be sealed to prevent circulation of air and prevent the cover from flapping or blowing. The protection shall remain in place until the concrete is seven days old. If construction operations require removal, the protection removed shall be replaced immediately after completion or suspension of such operations. This method may not be used on slope walls when structural steel or structural concrete is in place above.

#### **1020.14 Temperature Control for Placement.**

- (a) Portland Cement Concrete other than Structures. The temperature of mixed concrete immediately before placing, shall be not less than 10 °C (50 °F) nor more than 32 °C (90 °F). Aggregates and water shall be heated or cooled as necessary to produce concrete within these temperature limits.

When the temperature of the plastic concrete reaches 30 °C (85 °F), an approved retarding admixture shall be used or the approved water reducing admixture in use shall have its dosage increased by 50 percent over the dosage recommended by the Approved Admixtures list for the temperature experienced. This requirement may be waived by the Engineer when fly ash compensated mixtures are used.

Plastic concrete temperatures up to 35 °C (96 °F), as placed, may be permitted provided jobsite conditions permit placement and finishing without excessive use of water on and/or overworking of the surface. The occurrence within 24 hours of unusual surface distress shall be cause to revert to a maximum 32 °C (90 °F) plastic concrete temperature.

Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches 5° C (40° F) and not resumed

until an ascending air temperature in the shade and away from artificial heat reaches 2 °C (35 °F).

When placing of concrete is authorized during cold weather, the Engineer may require the water and/or the aggregates to be heated to not less than 20 °C (70 °F) nor more than 65 °C (150 °F). The aggregates may be heated by either steam or dry heat prior to being placed in the mixer. The apparatus used shall heat the mass uniformly and shall be so arranged as to preclude the possible occurrence of overheated areas which might damage the materials. No frozen aggregates shall be used in the concrete.

- (b) Temperature Control for Structures. Placing of concrete will be permitted only under the following conditions:

The temperature of the concrete mixture as placed in the forms shall be not less than 10 °C (50 °F) nor more than 32 °C (90 °F). When insulated forms are used, the temperature of the concrete mixture shall not exceed 25 °C (80 °F) and if it is determined by the Engineer that heat of hydration might cause excessive temperatures in the concrete, the concrete shall be placed at a lower temperature between 10 °C (50 °F) and 15 °C (60 °F), as directed by the Engineer. When concrete is placed in contact with previously placed concrete, the temperature of the mixed concrete may be increased as required to offset anticipated heat loss.

When the temperature of the plastic concrete reaches 30 °C (85 °F), an approved retarding admixture shall be used or the approved water reducing admixture in use shall have its dosage increased by 50 percent over the dosage recommended by the Approved Admixtures list for the temperature experienced. This requirement may be waived by the Engineer when fly ash compensated mixtures are used.

- (c) Temperature. The concrete temperature shall be determined according to ASTM C 1064.

## SECTION 1021. CONCRETE ADMIXTURES

**1021.01 General.** Admixtures shall be furnished in liquid form ready for use. The admixtures may be delivered to the job in the manufacturer's original containers, bulk tank trucks or such containers or tanks as are acceptable to the Engineer. Delivery shall be accompanied by a ticket which clearly identifies the manufacturer and trade name of the material. In all cases, containers remaining on the job shall be readily identifiable to the satisfaction of the Engineer as to manufacturer and trade name of the material they contain.

When AASHTO M 194 is specified, the test mixture shall contain a cement content of 335 kg/cu m (5.65 cwt/cu yd).

When ASTM C 672 is specified, the test mixture shall contain a coarse aggregate meeting the requirements of AASHTO M 43, gradation 67, and a cement content of 335 kg/cu m (5.65 cwt/cu yd), the deicing agent shall be rock salt (sodium

chloride) applied at a rate of 0.001 g/cu mm (2/3 gram/sq in.) of surface area. Tests shall be continued until 60 cycles have been completed. 200 mm x 250 mm (8 in. x 10 in.) glossy photos of each specimen will be required for evaluation by the Engineer, at the conclusion of testing.

Prior to approval of a product, two copies of a report prepared by a laboratory regularly inspected by the Cement and Concrete Reference Laboratory (CCRL) of the National Institute of Standards and Technology (NIST) shall be forwarded to the Engineer of Materials and Physical Research. The report shall show the results of physical tests using materials and methods specified on a "test" concrete and a "reference" concrete, together with a certification that no changes have been made in the formulation of the material since the performance of the tests. Prior to the final approval of any brand or type of admixture, the Engineer may conduct all or part of the applicable tests on a sample that is representative of the material to be furnished. The manufacturer shall submit to the Engineer a sample of not less than 4 L (1 gal). A field experimental section may also be required.

If the admixture previously has been approved by the Engineer, approval of its use will be granted upon the certification by the manufacturer that the admixture is of the same formulation as that previously approved. If minor changes have been made, the certification shall state that the admixture is essentially the same as previously approved, and the Engineer may conduct such tests as deemed desirable to check the properties of the material before approval is granted.

The manufacturer shall submit certification giving the average and manufacturing range of specific gravity at 25 °C (77 °F), the average and manufacturing range of solids in the solution based on the residue dried for 17 hours ( $\pm$  15 minutes) at 105 °C (221 °F), the average and manufacturing range of pH, and including an infrared spectrophotometer trace of current production material. The certification further shall state that, for all except chloride-based accelerators, the admixture contains no more than 0.3 percent chloride by mass. The material shall not be used until it has been shown to conform with the requirements.

Either prior to or after the start of construction, the Engineer may conduct further tests upon the admixture selected by the Contractor to assure conformity with the requirements. Any admixture failing to meet the requirements will be rejected.

**1021.02 Air-Entraining Admixtures.** Air-entraining admixtures shall conform to the requirements of AASHTO M 154, as modified by Note 1 in Article 1021.03(b). In the event that the air-entraining admixture is an aqueous solution of Vinsol resin that has been neutralized with sodium hydroxide (caustic soda), and provided that the manufacturer so certifies, tests for compliance with the requirements may be waived by the Engineer. In certification, the manufacturer shall show complete information with respect to the formulation of the solution, including the number of parts of Vinsol resin to each part of sodium hydroxide. Before the approval of its use is granted, the Engineer will test the solution for its air-entraining quality in comparison with a solution prepared and kept for that purpose, and a sample of not less than 1 L (1 qt) shall be submitted for this test.

**1021.03 Retarding and Water-Reducing Admixtures.** The admixture shall comply with the following requirements:

(a) The retarding admixture shall comply with the requirements of AASHTO M 194, Type B or Type D, and Illinois Modified ASTM C 672, in addition to Note 1 in (b).

(b) The water-reducing admixture shall comply with the requirements of AASHTO M 194, Type A, and Illinois Modified ASTM C 672.

Note 1. AASHTO T 161, Procedure B, shall be used.

(c) High Range Water-Reducing or Retarding Admixtures. The high range water-reducing or retarding admixture shall comply with the requirements of AASHTO M 194, Type F or Type G, and Illinois Modified ASTM C672.

Care shall be taken that water contents are not reduced to levels which will restrict cement hydration. Water-cement ratios shall not be lower than 0.32.

High range water-reducing or retarding admixtures may be used as plasticizing agents to obtain slumps outside those specified, subject to the following restrictions:

Water-cement ratios shall not exceed 0.42, 0.44, and 0.46 for fine aggregate Types A, B and C, respectively. The liquid admixture shall be counted as water in the calculation of the water-cement ratio.

An initial slump of 40 mm (1 1/2 in.) to 50 mm (2 in.) is recommended prior to addition of the high range water-reducing admixture. Final slump shall be no greater than is necessary for proper placement and compaction and in no case shall exceed 180 mm (7 in.) after addition of the high range water-reducing admixture.

Air tests will be performed after the addition of the admixture.

The high range water-reducing admixture shall be added at the jobsite unless otherwise directed by the Engineer. A high range water-reducing admixture, at a dosage rate not to exceed 40 percent of the original amount used, may be used to retemper concrete, provided set times are not unduly affected.

With permission of the Engineer, admixtures compatible with the high range water-reducing admixture may be used concurrently to facilitate placement and/or strength gain and/or to control set times.

**1021.04 Set Accelerating Admixtures.** The admixture shall comply with the requirements of AASHTO M 194, Type C or Type E, and Illinois Modified ASTM C 672 in addition to Note 1 in Article 1021.03(b).

**SECTION 1022. CONCRETE CURING MATERIALS**

**1022.01 Membrane Curing Compound.** Membrane curing compound shall be one of the following three types. The type used shall be that stipulated in the contract or authorized by the Engineer.

Type I. The curing compound shall be a clear transparent membrane without a fugitive dye.

Type II. The curing compound shall be a clear translucent membrane containing a fugitive dye. It shall not contain oils, waxes or other materials which would tend to prevent bonding of bituminous concrete surfaces.

Type III. The curing compound shall be white pigmented. It shall contain finely divided white pigment and vehicle, premixed for immediate use without alteration. When applied to concrete at the specified rate of application, the compound shall exhibit a daylight reflectance of not less than 60 percent of that of magnesium oxide.

Each type of membrane curing compound shall conform with the following:

- (a) The curing compound shall be of a consistency suitable for spraying, shall be relatively nontoxic, and shall adhere satisfactorily to a vertical or horizontal surface of damp concrete when applied immediately after the disappearance of surface water sheen. It shall not react harmfully with the components of concrete. The resulting film shall be continuous, uniform, moisture impermeable, free from pinholes, and shall not peel.
- (b) The curing compound, when applied to the surface of the mortar specimens in the determination of water loss, as specified, shall dry to touch in one hour and shall dry through in not more than four hours. When used in the field, it shall show drying properties satisfactory to the Engineer.
- (c) The curing compound shall not darken the natural color of the concrete. The fugitive dye when required shall have a color strength sufficient to render the film distinctly visible for at least one hour after application. The color of the fugitive dye shall disappear within seven days after application.
- (d) The curing compound shall be of such viscosity that it may be readily applied by approved pressure spraying equipment at temperatures above 4 °C (40 °F).
- (e) The curing compound shall be delivered to the job only in the manufacturer's original container, which shall be marked with the manufacturer's name, trade name of the material, and number or symbol with which test samples may be correlated.

Curing compounds which are flammable shall be so designated on the container.

- (f) Specimens used for determining moisture loss will be made and tested according to AASHTO T 155, except as follows:
- (1) The molds for the specimens will be standard pie tins having the shape of the frustum of a right cone, 135 mm (5 3/8 in.) in diameter at the top, 100 mm (4 in.) in diameter at the bottom and 24 mm (15/16 in.) in depth, or any other size and shape found necessary or desirable. The use of control specimens may be omitted.
  - (2) The flow of the mortar used in the specimens will be optional, but will be not greater than that specified by the AASHTO method. The sand used in the mortar will be natural sand conforming with the gradation specified by the AASHTO method. The mortar may be machine mixed, and the molds will be filled in one layer and struck off even with the top of the rim of the mold.
  - (3) The water lost from the specimens prior to the application of the curing compound will not be included in the results reported.
  - (4) Duplicate sets of specimens will be made. One set will be tested in the curing cabinet adopted for this purpose by the Department. The other set will be tested by placing each specimen, immediately after application of the curing compound, under a reflector spot lamp for a period of five hours. The distance between the lamps and the specimens will be adjusted to produce a temperature of 49 °C ± 2 °C (120 °F ± 3 °F) in the dry mortar specimens not coated with curing compound, kept for the purpose of calibrating the position of the lamps. During the test, air at room temperature will be blown constantly across the surface of the specimens.

In applying the curing compound to the surface of the specimens, the rate of spraying will be 200 mL/sq m (1 gal/200 sq ft) of surface, and the nozzle of the spray will be held from 125 to 150 mm (5 to 6 in.) above the surface of the specimens.

When tested in the curing cabinet, the average moisture loss of the specimens shall be not more than the following amounts of moisture per sq mm (sq in.) of exposed surface:

At 24 hours .....	.00012 g (0.075 gram)
At 72 hours .....	.00023 g (0.150 gram)
At 7 days .....	.00047 g (0.300 gram)

When tested under the reflector spot lamps for a period of five hours, the average moisture loss of the specimens shall be not more than 0.00016 g/sq mm (0.100 g/sq in.) of exposed surface.

- (g) All curing compounds will be tested by the Engineer. A sample of at least 4 L (1 gal) of any curing compound proposed for use shall be sent directly to the Engineer for preliminary tests at least 30 days before the proposed date

of use. Curing compounds which are flammable shall be so designated on the container.

No shipment of curing compound will be accepted for use unless it conforms to the requirements of the Specifications as indicated by the results of the tests of samples taken by an authorized representative of the Department from the material actually shipped.

No curing compound shall be used until the Contractor has been notified by the Engineer that it meets these requirements.

**1022.02 Burlap Curing Blankets.** Burlap blankets shall be made from whole stock widths of new burlap and shall be 600 mm (2 ft) longer than the width of the pavement. The burlap shall be free from substances which may be deleterious to freshly laid concrete. Sacks or burlap reclaimed from uses other than curing shall not be used. Reused burlap shall be in a condition satisfactory to the Engineer. The burlap shall conform to the following requirements:

- (a) Mass per sq m (sq yd), not less than 305 g (9 oz).
- (b) Ash (based on dry mass), not more than 3.0 percent.
- (c) The burlap shall be composed of not less than 95.0 percent jute and manila fibers.

**1022.03 Waterproof Paper Blankets.** Waterproof paper blankets shall meet the requirements of AASHTO M 171 and the following:

- (a) General Requirements. The paper composing the blankets shall be 100 percent sulphate kraft. The color of the top sheet shall be that which the paper industry terms "white" for this grade of paper and shall meet the approval of the Engineer.

Blankets shall be reinforced by jute, cotton, or glass yarn of satisfactory mass (weight), completely embedded in the bituminous cement, running in both longitudinal and transverse directions not more than 15 mm (1/2 in.) apart and crossing at approximately right angles. Unspun fibers may be used, in which case approximately 500 m/sq m (1400 ft/sq yd) shall be embedded in the bituminous cement in a manner that will provide adequate reinforcing in both longitudinal and transverse directions. A suitable bituminous cement shall be used.

- (b) Impermeability. When tested by the applicable parts of the method in Article 1022.01, mortar specimens having the surface sealed with samples of impermeable paper blanket proposed for use shall show moisture losses no greater than specified.
- (c) Tensile Strength. The specimens to be tested wet shall be immersed in water having a temperature between 21 °C and 24 °C (70 °F and 75 °F) for a period of one hour immediately prior to testing.

**1022.04 White Polyethylene Sheeting.** White polyethylene sheeting shall be of single sheet stock manufactured from virgin resin and shall contain no scrap or additives. It shall be not less than 100  $\mu\text{m}$  (4 mils) in thickness; shall be free from visible defects and of uniform appearance; and shall not easily tear, puncture or otherwise become unfit for use. Its color shall be white and shall meet the approval of the Engineer.

The sheeting shall meet the following physical requirements:

- (a) Impermeability. When tested by the applicable parts of the method prescribed in Article 1022.01, mortar specimens having the surface sealed with samples of the sheeting proposed for use shall show moisture losses no greater than specified.
- (b) Tensile Strength and Elongation. When tested according to ASTM D 882, Method B, the polyethylene sheeting shall have a tensile strength of not less than 11,700 kPa (1700 psi) in the machine direction and 8,300 kPa (1200 psi) in the transverse direction. The elongation shall not be less than 225 percent in the machine direction and 350 percent in the transverse direction. Tests shall be made at a temperature between 22 °C and 25 °C (72 °F and 78 °F).

**1022.05 Burlap-Polyethylene Blanket.** The burlap and polyethylene shall be bonded together so that the blanket acts as a unit. The burlap shall conform to the requirements of Article 1022.02. The polyethylene sheeting shall conform to the requirements of Article 1022.04. When tested by the applicable parts of the method prescribed in Article 1022.01, mortar specimens having the surface sealed with samples of the blanket proposed for use shall show moisture losses no greater than specified.

## SECTION 1023. PROTECTIVE COAT

**1023.01 Requirements.** Protective coat shall meet the requirements of AASHTO M 233 (boiled linseed oil) except the protective coat shall have a nonvolatile range of 53 to 57 percent and the petroleum spirits used in the production of the protective coat shall be Type I meeting the requirements of ASTM D 235 with a maximum copper corrosion rating of 2.

## SECTION 1024. NONSHRINK GROUT

**1024.01 Requirements.** Nonshrink grout shall be a flowable nonmetallic grout and nonshrink when tested according to the applicable portions of the Corps of Engineers "Specification for Nonshrink Grout", CRD-C621. The maximum expansion allowable in this test at 3, 14 and 28 days is 0.4 percent. The expansion at 3 and 14 days shall not be greater than the expansion at 28 days. The grout shall have a compressive strength of not less than 20,000 kPa (3000 psi) at an age of 24 hours when tested using applicable portions of ASTM C 109M (C 109). The compressive strength specimens shall be produced from a mixture of the dry grout and sufficient water to produce a flowable mixture. The initial set shall not be less than 60 minutes



when tested under CRD-C82, "Method of Test for Time of Setting of Grout Mixtures," Corps of Engineers. The resistance of the grout to freeze thaw shall be such that it maintains a relative dynamic modulus of elasticity of not less than 80 percent after 300 cycles when tested according to AASHTO T 161, Procedure B. The grout product may be accepted under certification that it meets the above requirements; however, the Department retains the right to perform any or all of the tests as a condition of approval.

## **SECTION 1025. EPOXY CONCRETE MATERIALS**

**1025.01 Adhesive.** The epoxy concrete adhesive shall be a two component, epoxy-resin system for use in bonding freshly mixed concrete to hardened concrete. The epoxy concrete adhesive shall conform to the requirements of ASTM C 881, Type V, Grade 2, Class B or C. The class supplied shall be governed by the range of temperatures for which the material is to be used.

The two component adhesive shall be furnished by the manufacturer in containers individually marked to clearly identify each component. The epoxy adhesive shall be packaged in a kit with each component in a separate container. The containers of each kit shall be filled with the adhesive components in exact mixing proportions and one container shall be large enough to mix both of the components. The size of the kit shall be the total volume of the mixed adhesive which shall be 4 L (1 gal) or 20 L (5 gal) as specified. The manufacturer shall supply mixing instructions. The adhesive shall be supplied as an unfilled, clear resin system. Prior to approval and use of the two component adhesive materials, the Contractor shall submit a notarized certification by the formulator of these materials, stating that they meet these requirements.

**1025.02 Epoxy Mortar.** The epoxy mortar shall consist of a two component epoxy-resin system suitably mixed with an aggregate of a type and gradation recommended by the manufacturer. The mortar shall have an initial cure period of not more than 24 hours.

The epoxy mortar shall be non-sagging and suitable for placement in vertical and overhead positions and shall be capable of bonding to damp concrete surfaces. The resin shall contain a white pigment and the hardener shall contain a black pigment in such proportions that the resulting mixture is concrete gray.

The binder in the epoxy mortar shall be a two component, epoxy-resin bonding system conforming to the requirements of ASTM C 881, Type III, Grade 3, Class A, B or C. The Class supplied shall be governed by the range of temperature for which the material is to be used.

The prime for bonding the epoxy mortar to the concrete shall be a two component, epoxy-resin system conforming to the requirements of ASTM C 881, Type III, Grade 1, Class A, B or C.

The system furnished shall be compounded for and specifically recommended by the manufacturer for the use specified. Prior to approval and use of the product furnished, the Contractor shall submit a notarized certification by the formulator of these materials, stating that they meet these requirements.

The epoxy adhesive shall be packaged in a kit with each component in a separate container. The containers of each kit shall be filled with the adhesive components in exact mixing proportions and one container shall be large enough to mix both of the components. The size of the kit shall be the total volume of the mixed adhesive which shall be 4 L (1 gal) or 20 L (5 gal) as specified.

**1025.03 Epoxy Bonding Compound.** The epoxy bonding compound used for grouting and sealing the cracks in the concrete shall be a two component, epoxy-resin bonding system conforming to the requirements of ASTM C 881, Type IV, Grade 1, Class A, B or C. The class supplied shall be governed by the range of temperature for which the material is to be used. The bonding compound shall be supplied as an unfilled, clear resin system.

The system furnished shall be compounded for and specifically recommended by the manufacturer for grouting non-moving damp cracks and voids in concrete. The two components shall be furnished in containers individually marked to clearly identify each component.

The epoxy adhesive shall be packaged in a kit with each component in a separate container. The containers of each kit shall be filled with the adhesive components in exact mixing proportions and one container shall be large enough to mix both of the components. The size of the kit shall be the total volume of the mixed adhesive which shall be 4 L (1 gal) or 20 L (5 gal) as specified. The manufacturer shall supply mixing instructions, specifying particularly how the components are to be combined in parts by mass (weight) or parts by volume.

Prior to approval and use of the product furnished, the Contractor shall submit a notarized certification by the formulator of these materials, stating that they meet these requirements.

**1025.04 Epoxy Grout.** The epoxy grout shall be a two component, epoxy-resin bonding system conforming to the requirements of ASTM C 881, Type IV, Grade 2, Class B or C. The Class supplied shall be governed by the range of temperatures for which the material is to be used. The resin shall contain a white pigment and the hardener shall contain a black pigment in such proportions that the resulting mixture is concrete gray.

The two component, epoxy-resin grout shall be furnished by the manufacturer in premeasured, preassembled cartridges suitably designed for mixing and application of the grout or in containers individually marked to clearly identify each component.

The epoxy adhesive shall be packaged in a kit with each component in a separate container. The containers of each kit shall be filled with the adhesive components in exact mixing proportions and one container shall be large enough to mix both of the components. The size of the kit shall be the total volume of the mixed adhesive which shall be 4 L (1 gal) or 20 L (5 gal) as specified. Regardless of how it is furnished, the manufacturer shall supply mixing instructions.

Prior to approval and use of the epoxy-resin grout, the Contractor shall submit a notarized certification by the formulator, stating that the epoxy-resin grout meets these requirements.

**1025.05 Reserved.****SECTION 1026. BRIDGE SEAT SEALER**

**1026.01 General.** Sealer types shall be according to the listing in AASHTO M 224 and additional types will be considered for use. The Department will maintain an approved list.

The sealer shall have a clear or amber color when dry.

The sealer shall be tested according to Illinois Modified ASTM C 672. The average visual rating of the test specimens treated with sealer, divided by, the average visual rating of the untreated test specimens shall not exceed 0.80 after 60 cycles.

**SECTION 1027. CHEMICAL ADHESIVE**

**1027.01 Chemical Adhesive Resin System.** The chemical adhesive resin system shall consist of a two part, fast-setting resin and filler/hardener. Materials shall be according to the Bureau of Materials and Physical Research's Policy memorandum "Chemical Adhesive Acceptance Procedures," and be listed on the Department's approved list.

**MASONRY AND DRAINAGE ITEMS****SECTION 1040. DRAIN PIPE, TILE, TUBING, DRAINAGE MAT AND WALLDRAIN**

**1040.01 Drain Tile.** Drain tile shall conform to the requirements of ASTM C 4. The tile furnished shall be that designated as Heavy-Duty Drain Tile. The maximum length of the units shall be 600 mm (24 in.).

**1040.02 Clay Pipe.** Extra strength clay pipe, extra strength perforated clay pipe and clay sewer pipe shall conform to the requirements of ASTM C 700.

**1040.03 Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.** These pipes shall conform to the requirements of AASHTO M 170M (M 170) Classes I to V, Tables I to V, except that the use of elliptical reinforcement in circular pipe will not be permitted and the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. When the concrete has attained the required strengths, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used based on past in-service satisfactory performance in the environment in which the product is to be used.

**1040.04 Concrete Sewer, Storm Drain, and Culvert Pipe.** These pipes shall conform to the requirements of AASHTO M 86M (M 86), except that the aggregate

#### Art. 1040.05 Drain Pipe, Tile, Tubing, Drainage Mat and Walldrain

shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. The pipe furnished shall be of the class designated. When the concrete has attained the required strengths, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used on past in-service satisfactory performance in the environment in which the product is to be used.

**1040.05 Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe.** These pipes shall conform to the requirements of AASHTO M 207M (M 207) except that the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. When the concrete has attained the required strength, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used based on past in-service satisfactory performance in the environment in which the product is to be used.

**1040.06 Concrete Drain Tile.** Concrete drain tile shall conform to the requirements of AASHTO M 178M (M 178) except that the minimum crushing strength shall be 20.5 kN/m (1400 lb/ft) and the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. When the concrete has attained the required strength, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used based on past in-service satisfactory performance in the environment in which the product is to be used.

**1040.07 Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe.** These pipes shall conform to the requirements of AASHTO M 206M (M 206) except that the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation.

**1040.08 Acrylonitrile-Butadiene-Styrene (ABS) and Polyvinyl Chloride (PVC) Composite Sewer Piping.** These pipes shall conform to the requirements of AASHTO M 264. Acceptance testing of ABS and PVC composite sewer piping shall be accomplished during the same construction season in which it is installed.

**1040.09 Perforated Polyvinyl Chloride (PVC) Pipe.** This pipe shall be according to AASHTO M 278 except it shall be made of PVC plastic having a minimum cell classification of 12454-C or 12364-C according to ASTM D 1784. Four rows of perforations at 50 mm (2 in.) centers will be acceptable for 300 mm (12 in.) and 375 mm (15 in.) diameter pipes.

**1040.10 Polyvinyl Chloride (PVC) Pipe.** This pipe shall be according to AASHTO M 278 or ASTM F 679 except it shall be made of PVC plastic having a minimum cell classification of 12454-C or 12364-C, as defined in ASTM D 1784. Acceptance testing of PVC pipe and fittings shall be accomplished during the same construction season. The section properties shall be according to AASHTO's Section 18. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties.

**1040.11 Perforated Corrugated Polyethylene (PE) Tubing.** When used for backslope drains or underdrains, tubing shall be according to AASHTO M 252. When used for underdrains the tubing shall have a minimum pipe stiffness of 317 kPa (46 psi) at five percent deflection and shall be capable of 60 percent vertical deflection in parallel plate loading without splitting or cracking. PE tubing and fittings shall not be

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exposed to direct sunlight for more than six months. Fabric envelope materials shall be stored in UV-resistant bags until just prior to installation. Acceptance testing of PE tubing shall be accomplished in the same construction season in which it is installed.

**1040.12 Corrugated Polyethylene (PE) Tubing.** When used for backslope drains or underdrains, this tubing shall be according to AASHTO M 252. When used for underdrains, this tubing shall have a minimum pipe stiffness of 317 kPa (46 psi) at five percent deflection and shall be capable of 60 percent vertical deflection in parallel plate loading without splitting or cracking. PE tubing and fittings shall not be exposed to direct sunlight for more than six months. Acceptance testing of PE tubing shall be accomplished in the same construction season in which it is installed.

**1040.13 Drainage Mat Underdrain.** Drainage mat underdrain shall be on the Department's approved list. Drainage mat underdrain shall be a flexible rectangular hollow mat consisting of a supporting drainage core of the width shown on the plans and a nominal of 25 mm (1.0 in.) thick, encased in and/or bonded to an approved geotechnical fabric envelope weighing not less than 135 g/sq m (4.0 oz/sq yd) fitting snugly around the core. The flow rate of the core shall be not less than 60 L (16 gal)/minute at a hydraulic gradient of 0.1, 30 mm (1.20 in.) of total head, nominal width and length of 300 mm (12 in.) specimen, when subjected to a normal stress of 200 kPa (30 psi) according to ASTM D 4716. Closed-cell foam rubber layers shall be used to model soil adjacent on both sides of the specimen. The compressive strength of the drainage mat underdrain shall be a minimum of 215 kPa (4500 lb/sq ft) with a maximum deflection of 20 percent, when tested between parallel plates according to ASTM D 695M (D 695) with the modification of 6 mm (1/4 in.) thick rubber cushions having standard hardness of  $80 \pm 10$  Shore A Durometer above and below the specimen. The drainage core shall be fabricated of polyethylene with a minimum cell classification of PE 112110 or better according to ASTM D 3350, or of PVC 12353 C or better according to ASTM D 1784, or other approved material. Drainage mat underdrain shall be furnished with approved fittings to connect with the type of pipe underdrain (special) used. The manufacturer of the drainage mat underdrain shall certify that the flow rate specified according to ASTM D 4716 is met and the resin used in the manufacture of the drainage core meets or exceeds the minimum cell classification requirements.

**1040.14 Perforated Corrugated Polyvinyl Chloride (PVC) Pipe With A Smooth Interior.** This pipe shall conform to the requirements of ASTM F 949. In addition, the top centerline of the pipe shall be marked so that it is readily visible from the top of the trench before backfilling, and the upper ends of the slot perforations shall be a minimum of ten degrees below the horizontal. Acceptance testing of PVC pipe and fittings shall be accomplished during the same construction season in which they are installed.

**1040.15 Corrugated Polyvinyl Chloride (PVC) Pipe With a Smooth Interior.** This pipe shall be according to ASTM F 949. Acceptance testing of PVC pipe and fittings shall be accomplished during the same construction season in which they are installed. The section properties shall be according to AASHTO's Section 18. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties.

Art. 1040.16 Drain Pipe, Tile, Tubing, Drainage Mat and Walldrain

**1040.16 Polyethylene (PE) Pipe with a Smooth Interior.** This pipe shall be according to ASTM F 714 (DR 32.5) with a minimum cell classification of PE 335434 as defined in ASTM D 3350. The section properties shall be according to AASHTO's Section 18. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties. The manufacturer shall also certify that the resin used in the manufacturer of the pipe meets or exceeds the minimum cell classification requirements. Storage and handling shall be according to the manufacturer's recommendations except in no case shall the pipe be exposed to direct sunlight for more than six months. Acceptance testing of this pipe shall be accomplished during the same construction season in which it is installed.

**1040.17 Reinforced Plastic Mortar (RPM) Pipe.** This pipe shall be according to ASTM D 3262 and shall have approved inverted bell and spigot joints with elastomeric seals conforming to ASTM F 477.

**1040.18 Polyethylene (PE) Profile Wall Pipe Liner.** Polyethylene (PE) Profile Wall Pipe Liner shall conform to the requirements of ASTM F 667 for sizes 200 mm to 375 mm (8 in. to 15 in.), and to ASTM F 894 for sizes 450 to 1050 mm (18 to 42 in.). All sizes shall have wall construction that presents essentially smooth internal and external surfaces. The pipe liner shall have a minimum pipe stiffness of 320 kPa (46 psi) at five percent deflection.

**1040.19 Perforated Corrugated Polyethylene (PE) Pipe With a Smooth Interior.** When used for backslope drains or underdrains, this pipe shall be according to AASHTO M 252. When used for underdrains, this pipe shall have a minimum pipe stiffness of 317 kPa (46 psi) at five percent deflection, and shall be capable of 60 percent vertical deflection in parallel plate loading without splitting or cracking. PE pipe and fittings shall not be exposed to direct sunlight for more than six months. Fabric envelope materials shall be stored in UV-resistant bags until just prior to installation. Acceptance testing of PE pipe shall be accomplished in the same construction season in which it is installed.

**1040.20 Corrugated Polyethylene (PE) Pipe With a Smooth Interior For Drains and Underdrains.** When used for backslope drains or underdrains, this pipe shall be according to the requirements of AASHTO M 252. When used for underdrains, this pipe shall have a minimum pipe stiffness of 317 kPa (46 psi) at five percent deflection and shall be capable of 60 percent vertical deflection in parallel plate loading without splitting or cracking. PE pipe and fittings shall not be exposed to direct sunlight for more than six months. Acceptance testing of PE pipe shall be accomplished in the same construction season in which it is installed.

**1040.21 Geocomposite Wall Drain.** Geocomposite wall drain shall be a flexible geocomposite consisting of a supporting structure or core, the soil side of which is bonded to an approved geotextile weighing not less than 120 g/sq m (3.5 oz/sq yd). The drainage core shall provide support to and be bonded to the geotextile at intervals not exceeding 30 mm (1 1/8 in.) in any direction, and shall permit unobstructed flow through not less than 75 percent of the geotextile. The flow rate of the core shall not be less than 125 L/min/m (10 gal/min/ft) at a hydraulic gradient of 1.0 when subjected to a normal pressure on the soil side face of 285 kPa (6,000 lb/sq ft). When tested in a sand box according to the Department's method at 285 kPa (6,000 lb/sq ft), the core deflection shall not exceed 20 percent. The core shall be fabricated of polyethylene with a minimum cell classification of PE 112110 according 902

to ASTM D 3350 or other approved material. Geocomposite wall drain shall be furnished with approved fittings to connect with outlet pipes and weep holes, shall have suitable approved splices and end, top and bottom caps to prevent the intrusion of backfill material into the core, and shall have approved fastening systems to secure the wall drain to the wall.

**1040.22 Corrugated Polyethylene (PE) Pipe with a Smooth Interior.** This pipe shall be according to AASHTO M 294. The pipe shall be Type S or D. Storage and handling shall be according to the manufacturer's recommendations except in no case shall the pipe be exposed to direct sunlight for more than six months. Acceptance testing of this pipe shall be accomplished during the same construction season in which it is installed.

**1040.23 Polyethylene (PE) Profile Wall Pipe.** This pipe shall be according to ASTM F 894. The section properties shall be according to AASHTO's Section 18. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties. Storage and handling shall be according to the manufacturer's recommendations except in no case shall the pipe be exposed to direct sunlight for more than six months. Acceptance testing of this pipe shall be accomplished during the same construction season in which it is installed.

**1040.24 Polyvinyl Chloride (PVC) Profile Wall Pipe--794.** This pipe shall be according to ASTM F 794 and have a minimum pipe stiffness of 317 kPa (46 psi). Acceptance testing of PVC pipe and fittings shall be accomplished during the same construction season in which it is installed. The section properties shall be according to AASHTO's Section 18 properties. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties.

**1040.25 Polyvinyl Chloride (PVC) Profile Wall Pipe--304.** This pipe shall be according to AASHTO M 304. Acceptance testing of PVC pipe and fittings shall be accomplished during the same construction season in which it is installed. The section properties shall be according to AASHTO's Section 18. This pipe will require the manufacturer's certification that the material meets AASHTO's Section 18 properties.

## SECTION 1041. BRICK

**1041.01 Building Brick (Made From Clay or Shale).** Building brick, made from clay or shale, shall conform to the requirements of AASHTO M 114. The brick shall be of the grade designated as Grade SW.

**1041.02 Concrete Building Brick.** Concrete building brick shall conform to the requirements of ASTM C 55. The brick shall be of the grade designated as Grade S-II.

## SECTION 1042. CONCRETE MASONRY UNITS

**1042.01 Requirements.** Solid concrete masonry units shall conform to the requirements of ASTM C 139 and hollow load-bearing masonry units shall conform to

the requirements of ASTM C 90 except that the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. When the concrete has attained the required strengths, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used based on past in-service satisfactory performance in the environment in which the product is to be used.

## **SECTION 1043. PRECAST REINFORCED CONCRETE MANHOLE SECTIONS**

**1043.01 Requirements.** Precast reinforced concrete manhole sections shall conform to the requirements of AASHTO M 199M (M 199) except that the minimum wall thickness shall be 75 mm (3 in.), and the aggregate shall conform to the requirements of Articles 1003.02 and 1004.02 with the exception of gradation. When the concrete has attained the required strengths, but not prior to four days after casting, the units may be loaded, shipped and used. Chert gravel may be used based on past in-service satisfactory performance in the environment in which the product is to be used.

## **SECTION 1044. FLAP GATE**

**1044.01 Cover.** The cover shall be cast iron, ASTM A 126, Class B, with necessary reinforcing ribs. It shall be fabricated with a lifting eye for manual operation, and with bosses to provide a pivot point connection with the links. Bosses shall be designed to place the hinge bolt in double shear when the gate is assembled. Pivot bosses shall be designed to limit the double hinge action, preventing the cover from rotating sufficiently to become wedged in the open position.

**1044.02 Frame.** The one-piece cast iron frame shall be according to requirements of ASTM A 126, Class B.

The frame shall have a raised section around the perimeter of the waterway opening to provide the seating face. The raised section shall provide a seating plane diverging, top to bottom, from the plane of the mounting flange to assist in a positive closure of the cover.

The frame shall be flat back or spigot back as designated on the plans. The spigot back gates shall be designed for attaching to corrugated steel pipe.

**1044.03 Seating Faces.** The cast iron seating faces on the seat and the cover shall be machined to a plane with a minimum 1.6  $\mu$ m (63 micro in.) finish.

The seating faces may be bronze conforming to the requirements of ASTM B 21M (B 21) - C48200 and shall be pneumatically impacted into dove - tailed grooves machined to 1.6  $\mu$ m (63 micro in.) finish for maximum water tightness. Resilient seat, neoprene or Buna-N, when specified, shall be bonded in a groove machined in the frame to provide a wide seating surface for the seating face machined on the cover.



**1044.04 Top Pivot Connection.** The top connections to the hinge links or arms shall be with pivot lugs or some other system which has double bosses to place the top hinge bolts in double shear when they are assembled through the links or arms. The connections shall be adjustable in the horizontal plane without removal of the cover from the gate links or arms. The adjustment shall allow the top pivots to be moved toward the gate seat for reduced sensitivity of the cover, or moved away from the gate seat, to provide opening with a minimum differential head.

**1044.05 Hinge Links or Arms.** The hinge arms connecting the cover and pivot lugs shall be high-tensile bronze, ASTM B 584-C86500, one-piece heavy duty cast iron, ASTM A 126, Class B, or high strength ductile iron, ASTM A 536, Gr. 65-45-12.

Each hinge link or arm shall have two pivot points, an adjustable lower pivot with limited rotation and a threaded upper hinge post to adjust flap gate sensitivity.

The bottom of the links or arms shall be provided with an adjusting screw to properly align seating faces on the cover with respect to the seat. The links or arms shall be designed to limit the double hinge action, preventing the cover from rotating sufficiently to become wedged in the open position.

Cast iron or ductile iron links or arms shall be provided with a commercial grade bronze bushing at each pivot point. The hinge pins designed in double shear shall be bronze, ASTM B 98M (B98) - C65500 or Type 304 stainless steel.

**1044.06 Reserved.**

**1044.07 Fasteners.** All anchor bolts, screws, and nuts shall be galvanized steel, ASTM A 307 and ASTM A 164 of ample section to safely withstand the forces created by operation shown on the manufacturer's gate schedule.

**1044.08 Painting.** All cast iron parts shall be grit-blast cleaned to base metal before painting. All ferrous parts of the flap gates shall be painted with a prime coat and shop coat. The paint shall be applied according to the manufacturer's standard practice.

All machined surfaces shall be coated with a water-resistant rust preventative coating.

## **FILLERS, SEALERS AND WATERPROOFING ITEMS**

### **SECTION 1050. POURED JOINT SEALERS**

**1050.01 Cold-Poured Joint Sealer.** Cold-poured joint sealer, cold application type shall comply with the requirements of ASTM D 1850-74.

**1050.02 Hot-Poured Joint Sealer.** Hot-poured joint sealer shall comply with the requirements of ASTM D 3405.

**1050.03 Polysulfide Joint Sealant.** The joint sealant shall be a polysulfide, Type S or Type M, Grade NS, Class 25 or 12 1/2, Use T, according to ASTM C 920.

## SECTION 1051. PREFORMED EXPANSION JOINT FILLERS

**1051.01 Methods of Sampling.** Two samples, each 300 mm (12 in.) in length and full width, will be taken for each 300 m (1000 ft) or fraction thereof. Individual samples will be taken from separate pieces of preformed expansion joint filler selected at random.

**1051.02 Methods of Testing.** In addition to Article 106.03, preformed expansion joint fillers will be tested as follows:

Extraction of Bitumen. The bitumen will be extracted by means of a Soxhlet extraction apparatus (large), equipped with a glass extraction shell having a round, perforated bottom. A small quantity of glass wool will be placed in the bottom of the extraction shell. Trichloroethylene shall be used as the extracting solvent. A sample weighing approximately 45 g will then be cut into narrow strips and packed in the shell above the glass wool. The residue in the shell, after complete extraction of the bitumen, will be thoroughly dried at a temperature of  $102^{\circ}\text{C} \pm 3^{\circ}\text{C}$  ( $215^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ), cooled, weighed, and the percent of bitumen determined by difference. Before extraction, the sample shall be dried for 3 hours in a constant temperature oven at  $163^{\circ}\text{C} \pm 3^{\circ}\text{C}$  ( $325^{\circ}\text{F} \pm 5^{\circ}\text{F}$ ).

**1051.03 Bituminous Preformed Joint Filler.** Bituminous preformed joint filler shall consist of bitumen, felt, and mineral.

The felt shall be roofing felt produced by the felting of vegetable and animal fibers. The felt shall be free from foreign substances, such as leather, rubber, straw, or wood.

The mineral shall consist of finely crushed slate, limestone, silica, sand, or similar mineral matter.

Roofing scrap may be used in the manufacture of joint filler provided the quality of felt and mineral are complied with.

The preformed joint filler shall not contain wood in ground form or otherwise, nor coarse fragments of any description, and the presence of straw or cornstalks used as a substitute for felt, or the presence of large particles of slate or other foreign matter will be deemed sufficient cause for rejection.

Bituminous preformed joint filler shall further comply with the requirements of AASHTO M 33 except that the percent of soluble material in the mastic portion will be based on an extraction made in trichloroethylene as specified in Article 1051.02.

**1051.04 Preformed Fiber Joint Filler.** Preformed fiber joint filler shall comply with the requirements of AASHTO M 213 except that suitable binders other than bituminous will be permitted.

**1051.05 Bituminous Preformed Inorganic Fiber Joint Filler.** This material shall consist of a preformed strip made from inorganic fibers securely bound together and uniformly impregnated with a suitable bituminous binder. This strip shall be reinforced with a layer of felt paper on each side and shall conform to the requirements of AASHTO M 213, except that the minimum load to compress the material to 50 percent of its thickness before test is waived.

**1051.06 Preformed Cork Joint Filler.** Preformed cork joint filler shall comply with the requirements of AASHTO M 153, Type II.

**1051.07 Preformed Self-Expanding Cork Joint Filler.** Preformed self-expanding cork joint filler shall comply with the requirements of AASHTO M 153, Type III.

**1051.08 Preformed Closed Cell Plastic Joint Filler.** Preformed closed cell plastic joint filler shall consist of an extruded, low density, expanded polyethylene plastic foam. It shall have a closed cell structure that is chemically inert and has no food value that would attract or support plant or animal life. The plastic foam shall be odorless and non-toxic, remaining flexible over a wide range of temperatures, and be resistant to chemicals and solvents.

In addition to the above, the filler shall comply with the following requirements:

(a) Physical Properties and Test Methods.

Physical Properties and Methods of Tests	ASTM
Compression, kPa (psi) at 10% deflection, not less than 5 at 80% deflection, not greater than 125	D 1056
Moisture Vapor Permeability Permeability mm (in.), less than 0.4	E 96
Water Absorption % by volume, less than 0.5 *Use conditioning procedure 4.1.1 at 50° ± 3 °C.	C 272*
Density kg/cu m (lb/cu ft), not less than 38.4 (2.40)	D 1564

(b) Dimensions and Tolerances. Measurements for conformance to dimensional specifications must be made on a unit of stock which has been allowed to condition for one hour or longer at a temperature of 23° C ± 6° C (73 °F ± 10 °F). If the unit of stock is packaged or is a part of a pallet, it must be removed from the package or pallet and allowed to condition free from the insulating effect of the package or pallet.

(1) The thickness shall have a tolerance of 13 mm (1/2 in.) and minus 0.

- (2) The width shall have a tolerance of 13 mm (1/2 in.) and minus 0.
  - (3) The length shall be such that both ends can be squared and the joint filler cut to the required length.
- (c) Appearance
- (1) Each piece of plank shall not contain more than three percent voids or hard spots.
  - (2) The surface shall be smooth and reasonably free of dents or appendages. All packaged products shall be free of surface dirt and packaging damages.
  - (3) The planks shall have no kinks or other deformities affecting straightness.

**1051.09 Preformed Flexible Foam Expansion Joint Filler.** Preformed Flexible Foam Expansion Joint Filler shall consist of a synthetic foam of isomeric polymers or other approved material in a small closed cell structure. It shall be chemically inert and have no food value that would attract or support plant or animal life. It shall be odorless and nontoxic, shall remain flexible over a wide range of temperatures, shall be compatible with hot poured joint sealer meeting the requirements of Article 1050.02 and shall have a melting point of 165 °C (330 °F) minimum.

In addition to the above, the filler shall comply with the following requirements:

- (a) Physical Properties, ASTM D 545, 13 mm (1/2 in.) test specimen.
- (1) Compression at 50 percent deflection..... 70 kPa (10 psi) min.  
170 kPa (25 psi) max.
  - (2) Extrusion ..... 5 mm (0.2 in.) max.
  - (3) Recovery ..... 97 percent min.
  - (4) Water absorption, volume..... 0.5 percent max.
- (b) Dimension and Tolerance. Measurements shall be made on a unit of stock that has been conditioned at a temperature of 24 °C ± 4 °C (75 °F ± 7 °F) for a minimum of 24 hours.
- (1) The thickness shall have a tolerance of 6 mm (1/4 in.) and minus 0.
  - (2) The width shall have a tolerance of ± 6 mm (1/4 in.).
  - (3) The length shall be equal to the lane width of the pavement and shall have a tolerance of ± 13 mm (1/2 in.).

## (c) Appearance

- (1) Each piece of plank shall not contain more than three percent voids or hard spots.
- (2) The surface shall be smooth and reasonably free of dents or appendages. All packaged products shall be free of surface dirt and packaging damages.
- (3) The planks shall have no kinks or other deformities affecting straightness.

**SECTION 1052. NEOPRENE EXPANSION JOINT**

**1052.01 Description.** Neoprene Expansion Joint shall consist of molded anchor blocks of elastomeric and steel, field assembled over continuous lengths of elastomeric sealing membrane, with incidental accessories, sealants, and adhesives, as shown on the plans and as specified.

Shop drawings of the details and material of the neoprene expansion joint and incidental accessories, sealants, and adhesives shall be submitted to the Engineer for approval.

**1052.02 Materials.** The materials for the neoprene expansion joints and accessories shall comply with the following requirements:

- (a) **Elastometric Materials.** The elastomeric materials of the compounds for anchor blocks and sealing membrane shall be virgin polychloroprene ASTM D2000, line call-outs 2BC, 515, A14, B14, C12, K11, 21,22, or ethylene propylene diene monomer (EPDM) AST SQ M 000, line call-outs 3BA, 515, A14, B13, F17, C12, K21, 22 having the following properties:

	ASTM STANDARD	REQUIREMENT
Durometer - Shore A	D 2240	50 min.
Tensile Strength	D 412	10,300 kPa (1500 psi) min.
Ultimate Elongation	D 412	200% min.
Compression Set 22 Hours		
@ 100 °C (212 °F)(Method "B")		
for Polychloroprene	D 395	35% Max.
@ 70 °C (158 °F) (Method "B")		
for EPDM		25% Max.
Low Temperature Brittleness		
(Method "A")	D 2137	Pass
Non-brittle after 3 min.		
@ 1 °C (34 °F)		
Ozone Resistance Procedure "B"	D 1149	No Cracks
- D 518 100 PPHM Ozone		
for 70 Hours @ 38 °C (100 °F)		
Sample Under 20% Strain		
Bond During Vulcanization		
(Method "B")	D 429	80% R

## Art. 1053.01 Preformed Elastomeric Compression Joint Seals for Concrete

When test specimens are cut from the finished product, a ten percent variation in "Physical Properties" will be allowed.

- (b) Steel reinforcement in anchor blocks. The steel reinforcement in anchor blocks shall be bonded to elastomer during vulcanization process and shall conform to ASTM A 570M (A 570) Grade D, AASHTO M 270, Grade 36, SAE 1020, or equal.
- (c) Adhesive and Sealant. The adhesive/sealant bedding compound for bonding the expansion joint seals to the concrete or steel seats shall be a polysulfide grout meeting the requirements of Federal Specification MMM-G-650B, Grade C with 50 percent filler material allowed.

The sealant for sealing between the ends of elastomeric anchor blocks, between edges of concrete block-out and anchor blocks, and for filling bolt hole cavities shall be a one or two part, non-sagging polysulfide or polyurethane black sealing compound meeting the requirements of Federal Specification TT-S-00230C, Type II.

Bedding and sealing compounds that do not meet the specifications shall not be used without prior approval of the Department. Other compounds submitted for approval will be evaluated on their ability to provide equivalent physical and functional properties.

- (d) Anchor Bolts, Threaded Rods, Washers and Nuts. Anchor bolts, threaded rods, washers and nuts shall either be stainless steel meeting the requirements of ASTM A 193M (A 193), Class 2 or shall conform to the requirements of AASHTO M 164M (M 164), zinc-coated according to Article 1006.08.
- (e) Automatically End Welded Threaded Studs, Washers, and Nuts. Automatically end welded threaded studs, washers, and nuts, shall be stainless steel meeting the requirements of ASTM A 193M (A 193). Welding and inspection of the threaded studs shall conform to Article 505.08(m).

**1052.03 Certification.** The Contractor shall furnish a certification by the manufacturer stating that the neoprene expansion joint and the accessory items meet the requirements approved by the Department. This will not constitute a waiver on the part of the Department of any requirements with respect to samples or samplings and the right is retained to perform any test deemed by the Department as necessary to qualify the materials.

## **SECTION 1053. PREFORMED ELASTOMERIC COMPRESSION JOINT SEALS FOR CONCRETE**

### **1053.01 Requirements.**

- (a) Preformed elastomeric compression joint seals shall meet the requirements of AASHTO M 220 with the following modifications for the low compression seals for concrete pavement joints:

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- (1) The maximum loss in tensile strength after oven aging shall be 20 percent.
- (2) The maximum loss in elongation at break after oven aging shall be 20 percent.
- (3) When tested according to the procedures of ASTM D 575, Method A, the preformed elastomeric compression joint seal shall comply with the following requirements:

Nominal Width of Seal (mm)	Minimum Force Required to Compress to 80% of Nominal Width of Seal (N/mm)	Maximum Force Required to Compress to 50% of Actual Width of Seal (N/mm)
20	0.5	2.1
30	0.7	2.1
50	0.7	2.1
90	0.7	2.1

Nominal Width of Seal (in.)	Minimum Force Required to Compress to 80% of Nominal Width of Seal (lb/in.)	Maximum Force Required to Compress to 50% of Actual Width of Seal (lb/in.)
13/16	3	12
1 1/4	4	12
2	4	12
3 1/2	4	12

- (b) The lubricant-adhesive used with the preformed elastomeric joint seals shall meet the requirements of AASHTO M 220 with the following additional requirements:
  - (1) Average net weight per L (gal) 0.94 kg (7.84 lb)  $\pm$  5 percent
  - (2) Solids content, by mass, according to ASTM D 1084: 25 percent  $\pm$  3 percent
  - (3) Film strength, minimum tensile strength, according to ASTM D 412: 15,800 kPa (2300 psi)
  - (4) Minimum elongation at breaking, according to ASTM D 412: 750 percent
  - (5) The lubricant-adhesive shall be accompanied by the manufacturer's certification of conformance with this Specification.

- (6) Any lubricant-adhesive not used within nine months of manufacture will be rejected.

## SECTION 1054. NONMETALLIC WATER SEALS

**1054.01 Description.** Nonmetallic water seals shall be either thermoplastic or rubber.

All nonmetallic water seals shall be produced by a process that will provide a dense, homogeneous material free from imperfections. The cross section of the water seal shall be such as to ensure anchorage into the concrete by means of enlarged ends and/or fins and shall be approved by the Engineer. Nonmetallic water seal shall be capable of effectively sealing the joints in concrete against the infiltration of moisture.

**1054.02 Polyvinyl Chloride (PVC) Water Seal.** The water seal shall be extruded from a specially compounded thermoplastic material consisting of a basic resin of polyvinyl chloride with additional resins, plasticizers, stabilizers, or other ingredient materials needed to provide a satisfactory water seal. Samples taken from the finished water seals shall meet the following requirements:

- (a) Tensile Strength. The tensile strength shall be not less than 10,300 kPa (1500 psi).
- (b) Elongation. The elongation shall be not less than 300 percent.
- (c) Cold Bend. Specimens 25 mm (1 in.) wide and approximately 150 mm (6 in.) long shall be cooled until the material is between  $-18^{\circ}\text{C}$  and  $-23^{\circ}\text{C}$  ( $0^{\circ}\text{F}$  and  $-10^{\circ}\text{F}$ ), then immediately bent 180 degrees around a mandrel 6 mm (1/4 in.) in diameter. The specimens shall show no cracking.
- (d) The material shall have a low water absorption, a high resistance to acids and alkalies, and little deterioration under accelerated aging tests.

**1054.03 Rubber Water Seal.** The water seal shall consist of natural rubber or a high grade synthetic rubber polymer compounded to produce satisfactory physical properties and aging characteristics. Samples taken from the finished water seals shall meet the following requirements:

- (a) Tensile Strength. The tensile strength shall be not less than 17,200 kPa (2500 psi).
- (b) Elongation. The elongation shall be not less than 400 percent.
- (c) Hardness. The Shore A Durometer hardness shall be 60 to 70.
- (d) Absorption. The absorption of water by weight shall be not greater than five percent.
- (e) Specific Gravity. The specific gravity shall be  $1.15 \pm 0.05$ .



- (f) **Strength After Aging.** The tensile strength after the air accelerated aging test of 48 hours in oxygen at 70 °C (158 °F) and 2,100 kPa (300 psi) shall be not less than 80 percent of the original tensile strength.
- (g) **Test Methods.** Tests will be made according to the following methods:
  - (1) Tensile Strength - ASTM D 412
  - (2) Elongation - ASTM D 412
  - (3) Specific Gravity - ASTM D 297
  - (4) Absorption - ASTM D 570
  - (5) Hardness - ASTM D 2240
- (h) **Test Samples.** The nonmetallic water seal will be sampled on the job or at the source of supply as determined by the Engineer. The Contractor shall furnish 450 mm (18 in.) samples representative of the material being furnished. At the option of the Engineer, the manufacturer of the water seal may be required to submit a statement that the material furnished conforms to these requirements.

## SECTION 1055. MASTIC JOINT SEALER FOR PIPE

**1055.01 Requirements.** Cold-applied bituminous sealer for culvert and sewer pipe joints shall be a bituminous material of such consistency that it can be applied to the joints with a trowel when the temperature of the air is between -7 °C and 38 °C (20 °F and 100 °F), or it shall be a preformed bituminous material that can be applied to the joints by hand. The bituminous material shall adhere to the concrete or clay pipe so as to make a watertight seal and shall not flow, crack, or become brittle when exposed to the atmosphere.

Trowelable mastic joint sealer for pipe shall meet the following specific requirements:

Penetration 25 °C (77 °F), 150 g, 5 sec, with cone .....	175-300
Loss on Heating, 163 °C (325 °F), 5 hr, 50 g, percent .....	20 max.
Inorganic content [complete burn, 645 °C to 760 °C (1200 to 1400 °F)], percent .....	15-40
Flow at 60 °C (140 °F), centimeters .....	0
Pliable at -17 °C (0 °F) .....	Yes

Trowelable mastic joint sealer for pipe shall be delivered to the project in suitable containers for handling and shall be sealed or otherwise protected from contamination. The container shall show the brand name, net volume or weight and the requirements for application.

**SECTION 1056. PREFORMED FLEXIBLE GASKETS AND MASTIC JOINT SEALER FOR SEWER AND CULVERT PIPE**

**1056.01 Requirements.** Preformed flexible gaskets and mastic joint sealer to be used for laying sewer and culvert pipe shall conform to the requirements of AASHTO M 198.

**SECTION 1057. EXTERNAL SEALING BAND**

**1057.01 Requirements.** External sealing band, mastic, and film shall conform to the requirements of ASTM C 877M (C 877).

**SECTION 1058. CONCRETE JOINT SEALER**

**1058.01 Requirements.** The sealing compound shall be a liquid polymer type compound produced by mechanically mixing on the jobsite, according to manufacturer's recommendations, a liquid base polymer with a suitable curing component to form a homogeneous, liquid mixture suitable for filling and adhering to joints by pouring.

The polymer compounds shall be of a consistency that will permit their use at all temperatures above 10 °C (50 °F) and shall be capable of completely filling the joint without formation of air holes or discontinuities.

Curing of the polymer compounds shall be by chemical reaction of the two components and not by evaporation of solvent or fluxing of harder particles. The sealant shall cure tack and tack-free to traffic within five to six hours at 21 °C (70 °F) and rising.

The materials forming the sealing compound shall comply with the following requirements:

Penetration, 25 °C (77 °F), 150 g, 5 sec, with cone	3-13 mm
Bond Extension Test, -29 °C (-20 °F), 3 cycles	
Dry concrete block	Pass*
Wet concrete block	Pass*
Flow at 93 °C (200 °F)	0-5 mm
Resilience Test - Recovery	
Air-cured	70 plus percent
Oven-aged	70 plus percent

\* None of the specimens shall develop any crack, separation, or other Opening in the sealing compound or between the sealing compound and Concrete block.

The backer rod shall be rod stock of polychloroprene, rubber or other approved material of the size designated. The rod material when tested for 50 percent compression at 25 °C (77 °F), according to ASTM D 1056, shall have a recovery of not less than 90 percent.

The joint materials shall be furnished by the manufacturer in containers of a type, size and kind commonly used for the purpose and so constructed as to insure acceptance and safe delivery by carriers. The shipping containers for the components of the sealing compound shall be clearly marked by the manufacturer with the name of material, name of manufacturer, brand name, weight, batch number, and recommended proportioning and handling procedures.

**1058.02 Certification.** Prior to approval and use of the materials, the Contractor shall submit a notarized certification by the formulator and manufacturer of these materials stating that they meet these requirements. The furnishing of the certification, however, does not preclude the requesting of samples and testing by the Engineer as specified prior to acceptance of the materials.

**1058.03 Testing.** The Engineer may require that the materials be tested prior to acceptance or the tests may be waived. When required, the tests shall be performed according to ASTM D 1191 except as herein modified. If so specified or if permissible by the manufacturer's recommendation, test specimens may be prepared by hand mixing in the designated proportions. If so specified by the manufacturer, the laboratory specimens shall be mixed by a laboratory size proportioning and mixing unit furnished by the manufacturer. The mixing and proportions shall be as recommended by the manufacturer.

All test specimens shall be conditioned or cured in air for 24 hours  $\pm$  1 hour at a temperature of  $24^{\circ}\text{C} \pm 3^{\circ}\text{C}$  ( $75^{\circ}\text{F} \pm 7^{\circ}\text{F}$ ).

- (a) Penetration. A 177 mL (6 oz) seamless ointment-can shall be overfilled with the compound, the excess overfill struck off with a spatula or similar tool, and set aside to cure. Care should be taken to avoid entrapment of air. Five penetration readings shall be taken at a distance of not less than 13 mm (1/2 in.) from the edge of the can. The results of the penetrations shall be recorded as the average of the five readings.
- (b) Bond. The test shall be run at  $-29^{\circ}\text{C} \pm 2^{\circ}\text{C}$  ( $-20^{\circ}\text{F} \pm 4^{\circ}\text{F}$ ) for three cycles. The test with wet blocks shall be made with blocks that have been immersed in water for a minimum of 24 hours, wiped free of water with a clean dry cloth and immediately assembled and filled.
- (c) Flow at  $93^{\circ}\text{C}$  ( $200^{\circ}\text{F}$ ). The specimens shall be trimmed immediately after filing. The test shall be made at  $93^{\circ}\text{C} \pm 1^{\circ}\text{C}$  ( $200^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ).
- (d) Resilience. A specimen shall be prepared as described above for the penetration test. Following the 24 hour air cure at  $24^{\circ}\text{C}$  ( $75^{\circ}\text{F}$ ), it shall be maintained in air at a temperature of  $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$  ( $77^{\circ}\text{F} \pm 2^{\circ}\text{F}$ ) for one hour. It shall then be placed in position in a penetrometer, ASTM D 5, except that a steel ball having a diameter of  $17.1\text{ mm} \pm 127\text{ }\mu\text{m}$  ( $0.675\text{ in.} \pm 0.005\text{ in.}$ ) attached to a shaft of 5.52 mm (0.2175 in.) diameter and 49 mm (1.9375 in.) long with a suitable extension for inserting in the penetrometer, shall be substituted for the needle. The total mass (weight) of the moving plunger shall be 75 g.

The ball shall be placed in contact with the surface of the specimen in air at  $25\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$  ( $77\text{ }^{\circ}\text{F} \pm 2\text{ }^{\circ}\text{F}$ ) and the indicating dial shall be set at zero. The ball shall be loaded manually to cause it to penetrate the specimen to a dial reading of 100 at approximately a uniform rate in ten seconds. The ball shall be locked in this position and held for five seconds, during which time the indicating dial shall be reset to zero. The locking mechanism shall then be released. At the end of 20 seconds, the indicating dial shall be read. Resilience of the original sample, expressed as a percentage, shall be reported as 100 minus the dial reading.

The specimen shall be placed in an air circulated oven at  $70\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$  ( $158\text{ }^{\circ}\text{F} \pm 2\text{ }^{\circ}\text{F}$ ) for 24 hours. It shall then be removed and held at room temperature for one hour. It shall be maintained in air at a temperature of  $25\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$  ( $77\text{ }^{\circ}\text{F} \pm 2\text{ }^{\circ}\text{F}$ ), for one hour and then tested for resilience as above described. The result shall be reported as resilience of the oven-aged sample.

## SECTION 1059. ELASTIC JOINT SEALER

**1059.01 Requirements.** The joint sealer shall be composed of a mixture of materials that will form a resilient and adhesive compound capable of effectively sealing joints and cracks in bituminous pavements against the infiltration of moisture and foreign material throughout repeated cycles of expansion, contraction, and impact, and that will not flow from the joint or be picked up by vehicle tires at summer temperatures. The joint sealer shall be free of all foreign material and shall be capable of being brought to a uniform, smooth pouring consistency suitable for completely filling the joints without inclusion of large airholes or discontinuities and without damage to the material.

The joint sealer shall be of the hot-poured elastic type complying with the requirements of ASTM D 3405 except a certification from the manufacturer or supplier of the sealer will be required, certifying that the sealer is compatible with and capable of adhering to bituminous concrete.

## SECTION 1060. WATERPROOFING MATERIALS

**1060.01 Description.** Waterproofing materials shall include asphalt primer, waterproofing asphalt, waterproofing asphalt emulsion, and butyl rubber membrane. All waterproofing materials used in a given construction shall be uniform in character, appearance, and consistency.

**1060.02 Sources of Supply.** All sources of supply shall be approved by the Department.

**1060.03 Measurement of Volume.** Measurement of volume of asphalt primer, waterproofing asphalt and waterproofing asphalt emulsion will be based on the volume of the material at  $15\text{ }^{\circ}\text{C}$  ( $60\text{ }^{\circ}\text{F}$ ). Volumes measured at higher or lower temperatures will be corrected to the volume of  $15\text{ }^{\circ}\text{C}$  ( $60\text{ }^{\circ}\text{F}$ ), using the Standard ASTM-IP Petroleum Measurement Tables, ASTM D 1250.

**1060.04 Delivery.** When waterproofing materials are not sampled at the source by a representative of the Department, they shall be delivered far enough in advance of their use on the work to permit the necessary tests to be made. Waterproofing materials shall be delivered in suitable containers or packages, plainly labeled to show the kind of material, the name of the manufacturer, and the lot or batch number. Each shipment shall be kept separate until the material has been accepted.

**1060.05 Methods of Sampling.** In addition to the requirements of Article 106.03 the waterproofing materials will be sampled in samples of butyl rubber membrane shall be 900 mm (3 ft) in length and full width of sheet.

**1060.06 Asphalt Primer for Waterproofing.** Asphalt primer for waterproofing shall be Rapid Curing Liquid Asphalt RC-70 as specified in Article 1009.08 and shall be used prior to the application of waterproofing asphalts: AWP-Type I and AWP-Type II.

**1060.07 Asphalt for Waterproofing: AWP.** Asphalt for waterproofing AWP shall be either Type I or Type II and shall conform to the requirements of ASTM D 449.

- |          |  |
|----------|--|
| Type I.  | For use in waterproofing below ground level. The asphalt shall be free from water and shall not foam when heated to a temperature of 177 °C (350 °F).  |
| Type II. | For use in waterproofing above ground level and for use in the construction of asphalt plank bridge floors. The asphalt shall be free of water and shall not foam when heated to a temperature of 204 °C (400 °F). |

**1060.08 Asphalt Emulsion for Waterproofing.** Asphalt emulsion for waterproofing shall be an anionic type emulsion of asphalt in water with an asphalt content of 60 to 65 percent and a Saybolt Fural viscosity at 25 °C (77 °F) of 20 to 80 seconds when tested according to AASHTO T 59. The asphalt residue recovered from distillation according to AASHTO T 59 shall conform to the requirements of ASTM D 449, Type I, asphalts for waterproofing, with the exception; the ring and ball softening point shall be excluded. In addition, the material shall meet the moisture retention requirements specified in Article 1022.01(f) and shall pass the following tests for resistance to water action, freeze recovery, and rain resistance:

- (a) Resistance to Water Action. When tested according to ASTM D 466, no lifting of the film or darkening of the water will be permitted.
- (b) Freeze Recovery. Freeze recovery shall be tested in the following manner. Soak an unglazed ceramic tile, as used in ASTM D 466, in distilled water for ten minutes. Then place the tile in a freezer until the ice crystals form on the surface, at which time the tile is removed from the freezer and immediately coated with emulsion at room temperature as per ASTM-D-466. The coated tile is then replaced in the freezer. After five hours, the tile is removed from the freezer and dried as per ASTM D 466. After drying, the tile is tested as

per ASTM D 466. No lifting of the film or darkening of the water will be permitted.

- (c) Rain Resistance. Rain resistance shall be tested as follows. Dampen 100 grams of dry 6 mm to 9 mm (1/4 in. to 3/8 in.) stone chips with 1 g of water. Add 5 g of emulsion to the damp chips and mix for two minutes. When mixing is completed, place the coated chips on a screen and immerse them in a container of water at room temperature allowing them to soak one minute without movement. After soaking, remove from the water and examine for loss of coating. No loss of coating will be permitted.

**1060.09 Butyl Rubber Membrane.** Butyl rubber membrane shall be 3 mm (1/8 in.) thick. Rubber membrane shall be a compound butyl elastomer of the IIR Family (Isobutylene-Isoprene rubber) conforming to the following requirements:

- (a) Butyl Membrane.

Color	Black	
Specific gravity	1.20 ± 0.03	ASTM D 297
Tensile strength	8300 kPa (1200 psi) (min)	ASTM D 412
Modulus at 300% elongation	4100 kPa (600 psi) (min)	ASTM D 412
Elongation	300% (min)	ASTM D 412
Tear resistance, die B	1034 kPa (150 psi) (min)	ASTM C 624
Hardness, shore A	55 ± 5 with 5 sec interval before reading	ASTM D 2240

Ozone resistance,  
70 hr at 38 °C (100 °F)  
in 50 PPHM Ozone;  
20% elongation ..... no cracks  
Heat Aging, 7 days at 116 °C (240 °F) ..... 70% of original properties  
Maximum vol. swell  
(Triscresyl Phosphate  
Immersion) 72 hr at 100 °C (212 °F) ..... 10  
Operating temperature range -40 °C to 135 °C (-40 °F to 275 °F)  
Water absorption, volume change ..... less than 1%

- (b) Adhesive. Adhesive for securing butyl rubber membrane and the protective cover shall be compatible to the membrane waterproofing and with the materials to which it is bonded. It shall remain workable to its brittle point [-40 °C (-40 °F)].
- (c) Rubber Cement. Rubber Cement for splicing rubber membrane shall be a self-vulcanizing butyl rubber compound conforming to the following requirements:

Viscosity No. 3 Zahn Cup [25 °C (77 °F)]	100 to 150 sec.
Total Solids	30% (min.)

- (d) Butyl Gum Tape. Butyl gum tape for splicing butyl membrane shall be black, unvulcanized butyl rubber with an 200 µm (8 mils) polyethylene film backing.

The tape shall be 0.8 mm (30 mils)  $\pm$  100  $\mu$ m ( $\pm$  4 mils) thick, including the backing.

**1060.10 Asphalt Plank.** The asphalt plank shall be plain asphalt plank conforming to the requirements of ASTM D 517.

**1060.11 Asphaltic Panel.** The asphaltic panel shall conform to the requirements of AREMA Specifications, Chapter 29 for Membrane Waterproofing, Section/Article 2.4.7.

## SECTION 1061. WATERPROOFING MEMBRANE SYSTEM

**1061.01 Description.** The waterproofing membrane system materials shall consist of a penetrating primer, coal tar pitch emulsion, fiber glass, slurry seal top coat and a sand asphalt seal protection layer.

**1061.02 Penetrating Primer.** The primer shall be a highly penetrating solution that is compatible with the coal tar pitch emulsion and suitable for use on portland cement concrete surfaces. Asphaltic primers will not be permitted.

**1061.03 Coal Tar Pitch Emulsion.** The coal tar pitch emulsion shall be compounded of heavy closed ring hydrocarbons dispersed in water by means of a combination of irreversible colloidal clays.

- (a) **Sampling and Testing.** Prior to approval and use of the material for coal tar pitch emulsion and penetrating primer, the Contractor shall submit a certification by the manufacturer of each material, stating that it meets these requirements. This shall not constitute a waiver on the part of the Department of any requirements with respect to samples and samplings, and the right is retained to perform any or all of the tests specified.
- (b) **Ingredient Materials.** The coal tar pitch used in production of this material shall have a specific gravity at 25 °C/25 °C (77 °F/77 °F) of 1.20 to 1.27. By continuous hot extraction with benzol, after digesting in toluol, the insolubles ordinarily described as free carbon shall not be less than 12 percent. A cylinder of the pitch 13 mm (1/2 in.) in diameter and 150 mm (6 in.) long which has been immersed in melting ice for at least 30 minutes shall withstand being bent double without developing cracks at the point of greatest deflection; a duplicate cylinder which has been immersed in melting ice for at least an hour shall withstand twisting for two complete turns of 360° each without showing cracks or fractures. The pitch shall not be fluxed back with light oils, solvents, or any other adulterants before or during the emulsification process. Since these characteristics are not subject to test after emulsification, they are to be certified by the manufacturer.

The emulsion shall contain no sulphite pitches, asphalt, bentonite, coal dust, soluble soaps, or sulphonic acid and shall have sufficient thixotropic property so that at temperatures of 21 °C (70 °F) it may be temporarily reduced with agitation, to applied liquidity without addition of adulterants, to provide easy workability with brush or squeegee, and then reset in place.

## (c) Properties.

- (1) Specific Gravity. A sample of the emulsion shall show a specific gravity at 25 °C/25 °C (77 °F/77 °F) of between 1.22 and 1.29.
- (2) pH. pH of the emulsion shall be 7.0 to 7.9 at 25 °C (77 °F).
- (3) Nonvolatile Matter. A sample of the emulsion when treated in an oven according to ASTM D 2939, shall show a minimum nonvolatile matter of 52 percent. This residue, when heated from room temperature to 270 °C (518 °F) in an oven within 30 minutes time, shall show a loss of not more than ten percent by mass (weight).
- (4) Ash Content. A sample of the residue from the determination of nonvolatile matter according to ASTM D 2939 shall show an ash content of 30 percent to 40 percent.
- (5) Resistance to Freezing. \* A sample of the emulsion fortified with antifreeze shall be tested according to ASTM D 244. After exposure to a temperature of -18 °C (0 °F) shall return to a homogeneous consistency with stirring.

\*NOTE: The emulsion shall be fortified with antifreeze where climatic conditions surrounding the material in transit or storage are such to make resistance to freezing necessary.

- (6) Consistency. The emulsion when spread to a thin film with a spatula on a sheet of standard 8.16 kg (18 lb) paper shall flow with a uniformly smooth nongranular consistency free from coarse particles which are either apparent or which cause film voids as the material is drawn out to a smear.
- (7) Flammability. The material shall be nonflammable when exposed to flame.
- (8) Drying Time. A test panel prepared according to ASTM D 2939, and exposed at a temperature of 25 °C (77 °F) and 50 percent relative humidity in activated air shall set for touch within three hours and set within four hours.

## (d) Cured Film Performance.

- (1) Resistance to Motor Oil, Gasoline, and Distilled Water. A 2 coat film of the emulsion with a minimum cured thickness of 1.5 mm (1/16 in.) shall be prepared on a 150 x 150 mm (6 x 6 in.) tile according to the Methods of Testing Films Deposited from Bituminous Emulsions, ASTM D 466. The cured film shall be tested according to ASTM D 466, using the above specified test liquids, except the test period shall be 48 hours. At the end of the test period, the test liquid shall be poured off and the film inside the ring impressions shall show no sign of film penetration nor loss of adhesion.



- (2) **Heat Test.** A 1.5 mm (1/16 in.) cured film of the emulsion shall be prepared and tested according to ASTM D 2939. At the end of the test period, none of the film shall have slipped below the reference line.
- (3) **Flexibility.** A 1.5 mm (1/16 in.) cured film of the emulsion shall be tested for flexibility according to ASTM D 2939. Immediately after bending, the film shall show no signs of cracking, flaking, or loss of adhesion.
- (4) **Resistance to Impact.** A 1.5 mm (1/16 in.) cured film of the emulsion shall be prepared on a 75 x 150 x 1.5 mm (3 x 6 x 1/16 in.) cold rolled and pickled steel plate for exposure in an accelerated weathering machine conforming to ASTM G 23, Type E or EH as listed in ASTM D 529. The film shall be cured with activated air at 25 °C (77 °F) at 50 percent relative humidity for 96 hours, then introduced into the weathering machine, and exposed to cycle B as described in the Recommended Practice for Accelerated Weathering Test of Bituminous Materials, ASTM D 529 for 120 hours. The test panel shall then be placed over a 60 mm (2 3/8 in.) hole in a wood block and a 0.91 kg (2 lb) steel ball shall be dropped from a level of 2.44 m (8 ft) directly above the block. The impact of the ball on the specimen panel over the hole shall not spall the film to reveal the metal.

**1061.04 Fiber Glass Fabric.** The fiber glass fabric shall conform to the requirements of the "Woven Glass Fabrics Treated for Use in Waterproofing and Roofing", ASTM D 1668, Type II or III, except that salvage edges will not be required, and the heat loss test shall not apply to coal tar pitch treated fabric.

**1061.05 Aggregate for Slurry Seal Top Coat.** The aggregate shall meet the requirements of Article 1003.01 be clean, dry, hard, and shall contain a minimum of dust. It shall be graded as follows:

<u>Sieve Size</u>	<u>Passing Percent</u>
2.36 mm (No. 8)	100
2.00 mm (No. 10)	90 - 100
1.18 mm (No. 16)	10 - 75
600 µm (No. 30)	0 - 10

**1061.06 Protection Layer.** The protection layer shall be a hot-mix-sand asphalt seal composed of the following materials:

- (a) **Bituminous Material.** The bituminous material shall be asphalt cement Grade PG58-22 or PG64-22 meeting the applicable requirements of Section 1009.
- (b) **Fine Aggregate.** The fine aggregate shall consist of sand, stone sand, or slag sand, Class B Quality or better, gradation FA 20, meeting the applicable requirements of Article 1003.01, except that no Type A or Type B sands will be allowed.

**SECTION 1062. REFLECTIVE CRACK CONTROL SYSTEM**

**1062.01 Reflective Crack Control System A.** The reinforcing fabric shall be a nonwoven polypropylene or other approved plastic fabric having the following properties:

Weight (ASTM D 3776) g/sq m (oz/sq yd), min	135 (4.0)
Grab Tensile Strength (ASTM D 4632) N (lb), min	400 (90.0)
Grab Elongation at Break (ASTM D 4632) %, min max.	40-100
Asphalt Retention L/sq m (gal/sq yd), min	0.9 (0.20)

The asphalt binder shall be PG58-22 or PG64-22 meeting the requirements of Article 1009.05.

**1062.02 Reflective Crack Control System B.** Waterproofing membrane interlayer shall incorporate a high strength fabric embedded in a layer of self-adhesive suitably plasticized bitumen with the following properties:

<u>Property</u>	<u>Value</u>	<u>Test Method</u>
Thickness	1.65 mm (0.065 in.), min.	
Permeance-Perms	1.0 (0.10) max	ASTM E 96 Procedure B
Tensile Strength	8.7 N/mm (50 lb/in.), min.	ASTM D 882 (modified for 25 mm (1 in.) opening)
Puncture Resistance (fabric)	90 kg (200 lb), min.	ASTM E 154
Pliability -12.7 mm (-1/2 in.)-mandrel	No cracks in fabric or plasticized bitumen	ASTM D 146

**1062.03 Reflective Crack Control System C.**

- (a) Asphalt. The grade of asphalt cement for the asphalt-rubber mixture shall comply with the applicable requirements of Article 1009.05 and shall be either PG52-28, PG58-28 or PG58-22.
- (b) Emulsified asphalt for tack coat shall be SS-1, SS-1h, CSS-1, CSS-1h and shall comply with the requirements of Article 1009.07.
- (c) Vulcanized Rubber. The granulated crumb rubber shall be 100 percent vulcanized and meet the following gradation requirements:

<u>Sieve Size</u>	<u>Percent Passing</u>
2.36 mm (No. 8)	100
2.00 mm (No. 10)	98-100
600 µm (No. 30)	0- 10
425 µm (No. 40)	0- 4

The specific gravity of the material shall be  $1.15 \pm 0.02$  and shall be free from fabric, wire, or other contaminated materials, except that up to four percent calcium carbonate may be included to prevent the rubber particles from sticking together.

Vulcanized rubber will be accepted by certification from the rubber supplier.

- (d) Diluent. The diluent shall be a solvent with an initial boiling point (IBP) of +350 when tested according to ASTM D 86.
- (e) Crumb Rubber Blend. The rubber shall be a blend of 40 percent powdered devulcanized rubber and 60 percent ground vulcanized rubber scrap specially selected to have a high natural rubber content. The blend shall meet the following specifications:

<u>Sieve Analysis</u> Sieve Size	<u>(ASTM D 1151)</u> % Passing
2.00 mm (No. 10)	100
600 $\mu$ m (No. 30)	60-80
300 $\mu$ m (No. 50)	35-70
150 $\mu$ m (No. 100)	10-25

The natural rubber content shall be a minimum of 30 percent by mass (weight), ASTM D 297M (D 297). The devulcanized rubber content of the blend shall be 40 percent by mass (weight) and shall be determined by a mill test as follows:

When 40-50 grams of rubber retained on the 600  $\mu$ m (30 mesh) sieve are added to the tight 150 mm (6 in.) rubber mill, the material should bond on the mill roll in one pass, and should usually be retained on the mill roll. This will indicate the presence of a suitable quantity of devulcanized rubber. The crumb rubber blend will be accepted by certification from the rubber supplier.

- (f) Extender Oil. Extender oil shall be compatible with all materials used and be a high flash, high viscosity resinous aromatic rubber extender oil.
- (c) Cover Aggregate. Aggregates for cover material shall meet the requirements of Article 1004.03 for Class A bituminous courses except only CA 14 or CA 15 will be allowed.

## **SECTION 1063. FIBERGLASS FABRIC REPAIR SYSTEM**

**1063.01 Requirements.** The Fiberglass Fabric Repair System shall consist of two components, fiberglass and bituminous adhesive.

The fiberglass fabric shall consist of a heavyweight high strength woven fiberglass roving conforming to the following physical properties:

Strip tensile strength, ASTM D 579 Modified 25 mm (1 in.) cut strip test, Procedure 2 Strain rate of 15 mm/min (0.5 in./min) in a CRE testing machine, 75 mm (3 in.) gage length, test both Warp and fill directions.	140 N/mm (800 lb/in.) min
Mass (Weight)	745 g/sq m (22 oz/sq yd), min

The Bituminous Adhesive shall consist of an asphaltic polymer that has high adhesion and low tack and is compatible with the fiberglass fabric, and shall conform to the following physical properties:

Penetration, ASTM D 5 @ 25 °C (77 °F), 100g, 5 sec .....	30-60
Softening Point, ASTM D 36 .....	82 °C to 116 °C (180 °F to 240 °F)
Viscosity, ASTM D 3236 @ 193 °C (380 °F)	
Pas (centipoise) .....	0.8-2 (800-2000)
Thermal Stability, ASTM D 3407 Prolonged Heating Method, 6 hrs @ 205 °C (400 °F) and the retested sample shall conform to the requirements above and the following:	
Low Temperature Flexibility, ASTM C 711 Mod .....	-23 °C (-10 °F) (max.)
[25 mm (1 in.) diameter mandrel]	

The Fiberglass Fabric Repair System shall consist of the fabric coated on both sides with bituminous adhesive and shall conform to the following physical properties:

Strip tensile strength, ASTM D 579 Modified .....	175 N/mm (1000 lb/in.) min.
25 mm (1 in.) cut strip test, Procedure 2 Strain rate of 15mm/min (0.5 in./min) in a CRE Testing machine, 75 mm (3 in.) gage length, test both warp and fill directions.	

**LIGHTING****SECTION 1064. RESERVED****SECTION 1065. PROTECTIVE DEVICES****1065.01 Fuseholders and Fuses.****(a) Standard Fuseholders.**

- (1) General. Each fuse holder shall consist of a two-section unit designed to hold small-dimension cylindrical fuses of the type required. Each section shall be permanently marked with line and load side designations. A captive nut on one section which shall mate a threaded portion of the other section and the unit shall have an "O" ring which shall provide a water and vapor-tight seal when the sections are joined. Two pole fuseholders shall be used unless otherwise specified.

The terminals and the contacts in the fuseholder shall be made of annealed copper. The contacts shall be spring loaded to exert contact pressure on mating parts. Fuse holders shall be rated for 30 A at 600 V.

- (2) Single Pole Fuseholder. Single pole fuseholders shall have a molded plastic housing. Wires shall attach to the fuse holder by a crimping operation except that connection of No. 2 wires to breakaway fuse holder receptacles may be via a set screw connection. Each fuse holder shall be of a size proper for the wires to be attached. The assembly shall be provided with insulating boots.
- (3) Two Pole Fuseholders. Two pole fuse holders shall have a neoprene rubber housing. Phase to phase circuit applications shall be designed so that both phase conductors are disconnected at the same time.

**(b) Quick Disconnect Fuseholders. Quick disconnect type fuse holders shall be as specified for standard fuse holders with the following additional features:**

- (1) General. Where breakaway devices are used, a quick disconnect fuseholder shall be specified. The fuse holder shall be capable of disconnecting upon sufficient tension in the connected wires, as in a pole knockdown.

The fuse shall remain enclosed in the de-energized portion of the fuseholder upon disconnection. The fuse shall not be utilized as the disconnection means.

- (2) Single Pole Fuseholder. For the molded plastic fuseholder a separate plug and receptacle shall be utilized for the disconnection means..

The molded plastic fuse holder assembly shall mate a line-side quick disconnect receptacle. Line side wires shall attach to the receptacle by crimping operation.

Fuse holders for neutral conductors shall have a permanently installed solid neutral conductor and a white plastic coupling nut and screw section.

- (c) Fuses for installation within fuse holders for protection of luminaires shall be small-dimension cylindrical fuses of the dual element time-delay type with current limiting characteristics. The fuses shall be rated for 600 V AC and shall have a UL listed interrupting rating of not less than 10,000 rms symmetrical amperes at rated voltage. They shall be sized at 300 percent of the starting or operating current whichever is greater, but in no case greater than 50 percent of the branch circuit conductor ampacity.

**1065.02 Lightning Protection.** The surge protector shall be totally weatherproof, and shall withstand a surge current up to 20,000 amperes (8 X 20 micro seconds) and repetitive surges of 200 amperes for a minimum of 10,000 occurrences. Response time shall be less than 50 nanoseconds. The current drain shall not exceed 100 microamperes. The unit shall not allow holdover current or conduction to ground after the surge ends.

Protection shall be achieved for both phase and neutral conductors with surges being passed to ground and not to neutral. There shall be no discharge lag in the protection of phase conductors over the neutral conductor.

## SECTION 1066. WIRE AND CABLE

**1066.01 Unit Duct.** The unit duct shall be an assembly of insulated conductors which are factory pre-installed in a coilable nonmetallic conduit. The polyethylene duct shall be extruded directly over the cable at the factory in long continuous lengths. The unit duct shall be according to NEC Article 343.

### 1066.02 Conductors.

- (a) General. All cable shall be rated 600 V. The cable shall be rated 105 °C dry and 90 °C wet and shall be suitable for installation in wet and dry locations, and shall be resistant to oils and chemicals. Any cable used for a service entrance shall have a Type USE-2 rating.

The UL listing mark, cable voltage, insulation type and ratings, as well as the cable size shall all be clearly printed on the cable in a color contrasting with the insulation color. When specified, each cable installed shall be identified with its complete circuit number at each termination, splice, junction box or other location where the wire is accessible.

All electric cables installed shall be color coded. Neutral wires shall be color coded white. Single phase three wire runs of cable shall be color code one

black, one red, and one white; three phase three wire runs of cable shall be color coded one black, one red, and one blue. Single phase two wire runs shall be similarly color coded based on the applicable phase(s) and neutral. Insulated ground wires, where applicable, shall be green. Color striping of cables will not be acceptable in lieu of the specified color coding means.

Cables sized larger than No. 2 AWG shall be color coded as specified having not less than 300 mm (12 in.) of cable ends field-taped with half-lapped color tape or by other means approved by the Engineer.

- (b) Copper Conductors. Conductors shall be uncoated or coated copper.

Uncoated conductors shall be according to ASTM B3, ICEA S-68-516, NEMA No. WC-8, and UL Standard 44. Coated conductors shall be according to ASTM B 33, ASTM B 8, ICEA S-68-615, NEMA No. WC-8 and UL Standard 44.

All conductors shall be stranded. Stranding shall meet ASTM B 8 (or ASTM B 496 for conductors larger than No. 2 AWG), ICEA S-68-516, NEMA No. WC-8 and UL Standard 44. Uncoated conductors shall meet ASTM B 3, ICEA S-68-516, NEMA No. WC-8 and UL Standard 44.

- (c) Aluminum Conductors. Conductors shall be aluminum according to ASTM B 230 and shall be Class B stranded according to ASTM B 231, and shall conform to the values listed in the table in Article 1066.03.

### **1066.03 Cable Insulation.**

- (a) XLP Insulation.

- (1) General. Insulation cable designated as XLP shall incorporate cross-linked polyethylene (XLP) insulation and shall meet or exceed the requirements of ICEA S-66-524, NEMA Standard Publication No. WC-8, and UL Standard 44. Minimum insulation thickness at any point shall not be less than 90 percent of the average insulation's thickness listed in the following tables.
- (2) Non-Aerial. Cables sized No. 2 AWG and smaller shall be solid color coded with XLP insulation of minimum average thickness as indicated in the following table:

Insulation Thickness for  
Cables No. 2 AWG and Smaller

Conductor Size, AWG	Average Insulation Thickness
No. 10 and Smaller	1.1 mm (45 mils)
No. 8 through No. 2	1.5 mm (60 mils)

Cables larger than No. 2 shall be insulated by XLP insulation over the conductor with minimum average thicknesses not less than indicated in the following table:

Insulation Thickness for  
Cables Larger than No. 2 AWG

Conductor Size, AWG	Average Insulation Thickness
No. 1 through No. 4/0	2 mm (80 mils)
250 MCM through 500 MCM	2.4 mm (95 mils)

- (3) Aerial Cable Insulation. The conductors shall have the minimum average insulation thickness indicated in the following table:

Aerial Electric Cable Properties

Phase Conductor		Messenger wire			
Size AWG	Stranding	Average Insulation Thickness		Minimum Size AWG	Stranding
		mm	mils		
6	7	1.1	(45)	6	6/1
4	7	1.1	(45)	4	6/1
2	7	1.5	(60)	2	6/1
1/0	19	1.5	(60)	1/0	6/1
2/0	19	1.5	(60)	2/0	6/1
3/0	19	1.5	(60)	3/0	6/1
4/0	19	1.5	(60)	4/0	6/1

- (b) EPR Insulation. Cable insulation shall incorporate ethylene propylene rubber (EPR) as specified and the insulation shall meet or exceed the requirements of ICEA S-68-516, NEMA Standard Publication No. WC-8, and UL Standard 44, as applicable.

Cables sized No. 2 AWG and smaller shall be insulated with EPR insulation over the conductor with a minimum average thickness as indicated in the first table below or may be insulated with a bonded composite insulation of EPR insulation and a chlorosulfanated polyethylene jacket with a minimum average thickness as indicated in the second table:

Single Material Insulation Thickness	
Conductor Size, AWG	Average Insulation Thickness
No. 10 and Smaller	1.1 mm (45 mils)
No. 8 through No. 2	1.5 mm (60 mils)



Bonded Composite Insulation Thickness		
Conductor Size, AWG	Average EPR Thickness	Average Jacket Thickness
No. 10 and Smaller	0.8 mm (30 mils)	0.4 mm (15 mils)
No. 8	1.1 mm (45 mils)	0.4 mm (15 mils)
No. 6 through No. 2	1.1 mm (45 mils)	0.8 mm (30 mils)

Cables larger than No. 2 shall be insulated by EPR insulation over the conductor and a chlorosulfanated jacket overall, with the minimum average thicknesses as follows:

Average EPR & Jacket Insulation Thickness for Conductors Larger than No. 2 AWG		
Conductor Size, AWG	Average EPR Thickness	Average Jacket Thickness
No. 1 thru No. 4/0	1.4 mm (55 mils)	1.1 mm (45 mils)
250 MCM thru 500 MCM	1.6 mm (65 mils)	1.6 mm (65 mils)

Minimum insulation thickness at any point shall not be less than 90 percent of the average insulation's thickness listed in the tables in Article 1066.03.

**1066.04 Aerial Cable Assembly.** The aerial cable shall be an assembly of insulated aluminum conductors according to Articles 1066.02 and 1066.03 and a steel messenger wire according to ANSI/ICEA S-76-474. The cable assembly may have the messenger wire intertwined with the insulated cables or lashed to the insulated cables by a factory wrap.

The cable shall be assembled according to ANSI/ICEA S-76-474.

**1066.05 Underground Cable Marking Tape.** The tape shall be 150 mm (6 in.) wide; consisting of 0.2 mm (8 mil) polyethylene according to ASTM D882, ASTM D1682, and ASTM D2103. The tape shall be red with black lettering or red with silver lettering reading "CAUTION – ELECTRICAL LINE BURIED BELOW".

When specified, the tape shall have reinforced metallic detection capabilities consisting of a woven reinforced polyethylene tape with a metallic core or backing.

#### **1066.06 Splicing and Termination of Electric Cable.**

- (a) General. Splices in electrical cables shall be made with materials which are compatible with conductors, insulations, and any jackets of the associated cables. The connectors shall be listed for the quantity and size of conductors to be spliced.
- (b) Capped Splice. When specified, splices above grade, such as in poles and junction boxes, shall have a waterproof sealant and a heat shrinkable plastic cap. The cap shall be of a size suitable for the splice and shall have a factory applied sealant within. Additional seal of the splice shall be assured by the application of sealant tape or the use of a sealant insert prior to the installation of the cap. Either method shall be compatible with the cap

sealant. Tape sealant shall be applied in not less than one, half-lapped layer for a length at least 6.35 mm (1/4 in.) longer than the cap length and the tape shall also be wrapped into the crotch of the splice. Insert sealant shall be placed between the wires of the splice and shall be positioned to line up flush or extend slightly past the open base of the cap.

The end caps shall have a post shrink wall thickness not less than the following:

<u>Initial Inside Diameter</u>		<u>Post-Shrink Wall Thickness</u>	
mm	(in.)	mm	(in.)
13	0.50	1.78	0.070
19	0.75	2.03	0.080
25	1.00	2.41	0.095
29	1.15	2.41	0.095
38	1.50	2.54	0.100
50	2.00	2.67	0.105

- (c) Taped Splice. Remove 150 mm (6 in.) of insulation for compression splices or 75 mm (3 in.) of insulation for pressure connectors from the end of the cable and thoroughly clean the conductor for splicing. Apply the connector according to manufacturer's recommendations. Apply three layers of half-lapped rubber tape or one layer of 3 mm (1/8 in.) thick electrical insulation putty. The tape or putty shall completely enclose the bare splice and a minimum of 50 mm (2 in.) of insulation on each cable. Work the tape or putty with finger pressure to fill irregularities and form a smooth mold. Next apply two half-lapped layers of plastic electrical tape covering all rubber or putty filled areas and extending a minimum of 25 mm (1 in.) over the insulation of each cable. Brush on and completely cover the splice with a clear sealant and bonding compound that is specifically formulated for plastic electrical tape. Orient the finished splice so that the cables enter the splice from below.
- (1) Pressure Connectors. When specified, waterproof pressure type connectors may be used for #6 or smaller copper conductors in conductor combinations recommended by the manufacturer. High quality factory applied contact paste and sealant shall be supplied inside the connectors. Pressure connectors shall be covered with a tape sealant as noted above or with an Engineer approved sealant system after they are installed.
- (2) Compression Connectors. Individual conductors, including ground conductors, shall be terminated with compression terminals sized appropriately for the given connection. The connectors shall be copper and comply with UL Standard 486A. The terminals shall be clearly marked with the wire size and die index. All compression terminals shall be installed with the proper tool and die for crimping. Grounding conductors shall be connected to poles, sign structures, and the like using materials specifically listed for the applicable grounding. Connections at metal boxes or enclosures shall be made by means of a

suitable grounding screw used for no other purpose or by a listed grounding device. Splices for multiple conductors shall be copper compression joint sleeves. Copper compression joints (sleeves) shall be made of tin plated copper and be UL listed for 600 volt applications and shall be of the type suitable for a range of conductor combinations. Compression connectors shall be covered with a tape sealant as noted above or with an Engineer approved sealant system after they are installed.

#### **1066.07 Wiring Identification Markers**

- (a) Cloth Tape Wire Markers. Wire identification shall be made by the application of self-sticking wire markers, wrapped around the wire. The markers shall have black characters not less than 8 mm (5/16 in.) high on a white or yellow background. Markers shall be in strips not less than 38 mm (1 1/2 in.) long and shall be made of a high-tack cloth tape with printing protected by a clear, permanent overcoating.
- (b) Clip-On Wire Markers. Clip-on wire markers shall be white with black lettering. The individual letters shall interlock to keep the letters aligned. Wire markers shall meet Military Specifications MIL-H-5606 and MIL-L-7808. The proper size of wire markers shall be used to prevent slipping of the markers on the cable.

**1066.08 Electrical Tape.** Electrical tape shall be all weather vinyl plastic tape resistant to abrasion, puncture, flame, oil, acids, alkalies, and weathering, conforming to Federal Specification HH-I-595. Thickness shall not be less than 0.215 mm (8.5 mils) and width shall not be less than 20 mm (3/4 in.).

#### **1066.09 Wire in the Pole.**

Pole wire shall run from handhole to luminaire. Pole wire shall be sized No. 10, rated 600 V, RHW/USE-2, and have copper conductors, stranded in conformance with ASTM B 8. Pole wire shall be insulated with cross-linked polyethylene (XLP) insulation or ethylene propylene (EPR) insulation with a chlorosulfanated polyethylene jacket.

Color coding of the pole wire shall be via solid insulation color. Neutral wires shall be white and phase conductors shall be color coded red or black as appropriate to match the associated branch circuit conductors. Cable identification marking shall be visible in a contrasting color.

### **SECTION 1067. LUMINAIRE**

#### **1067.01 Roadway Luminaires.**

- (a) General. The luminaire shall be optically sealed, mechanically strong and easy to maintain. The luminaire shall be designed as to its size, shape and weight so it does not aggravate the vibration characteristics of its respective pole and it shall be compatible with the pole and arm.

- (1) Lamp Socket. The lamp socket shall be mogul type, porcelain enclosed, and be provided with grips, or other suitable means to hold the lamp against vibration. The rating of the socket shall exceed the lamp starting voltage, or starting pulse voltage rating.
- (2) ANSI Identification decal. A decal, complying to the ANSI standard, shall be factory attached permanently to the luminaire. The information contained in the decal shall enable a viewer, from the ground level, to identify the lamp wattage and type of luminaire distribution.
- (3) Optical Assembly. The reflector shall be made of aluminum sheet of such grade quality that the reflecting surface shall have a specular finish, the reflection factor of the reflecting surface, as determined by the A.H. Taylor or Baumgartner Reflectometer, shall not be less than 78 percent and the reflecting surface shall have a dense protective coating of oxide not less than 0.012 mg/sq mm (7.5 mg/sq in.), applied by the anodic oxidation process.

The reflector, the refractor or lens, and the entire optical assembly shall not develop any discoloration over the normal life span of the luminaire.

The luminaire shall be photometrically efficient. Luminaire efficiency, defined by the I.E.S. as "the ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used within", shall not be less than 67 percent. Submittal information shall include published efficiency data.

- (4) Gasketing. When closed for operation, the optical assembly shall be sealed with a gasket against the entry of moisture, dirt, and insects. The cover-reflector and socket-reflector junctions shall be sealed against the entry of moisture, dirt and insects with a thick, high density dacron felt gasket, securely attached by mechanical means, such as a retaining lip, or by a wide-temperature permanent adhesive in a manner acceptable to the Engineer. Submittal information shall include data relative to gasket thickness and density and the means of securing it in place. An alternative gasket material may be approved by the Engineer. There shall be a provision for thermal breathing. A charcoal filter may be used, subject to approval by the Engineer.
- (5) Ballast
  - a. General. The ballast shall be integral to the luminaire. Integral ballast components shall be mounted in the rear of the luminaire on the inside of a removable door or on a removable mounting pad. Ballast wiring and lamp socket wiring shall be connected by means of a plug. Upon unplugging the ballast wiring the entire ballast assembly shall remove for maintenance. The mounting adjustments and wiring terminals shall be readily accessible. The removable door or pad shall be secure when fastened in place and all individual components shall be secure upon the removable

element. Each component shall be readily removable for replacement.

Ballasts shall maintain a power factor of 0.9 or higher under all assigned loading conditions..

Ballasts shall not be noisy. Noticeable noisy ballasts, as determined by the Engineer, shall be replaced at the Contractor's expense.

The ballast shall provide lamp operation within lamp specifications for the rated lamp life at its input design voltage range. It shall have a six month operation capability with a cycling lamp.

Submittal information shall include manufacturer's literature and data to confirm compliance with all specified requirements including an ANSI Standard Ballast Characteristic Graph (Trapezoid) diagram, with all items clearly identified.

The lampholder and ballast components shall be completely wired, with connections made to a heavy duty terminal board with plug-in (pressure) connectors. Leads shall not be smaller than #16 AWG conductors. These shall be coded by tagging and/or color coding for proper identification. A complete legible wiring diagram coordinated with the wire identifications shall be displayed at a convenient location on the interior of the luminaire. The lamp socket shall be mogul type, glazed porcelain, one piece rolled threads with stationary socket lead connectors that will not move during lamp insertion and removal. It shall be provided with a grip or suitable device to hold the lamp against vibration.

- b. High Pressure Sodium Reactor. The ballast shall be a high power factor, linear type, low loss reactor which is designed and rated for operation on a 240 V, grounded neutral system. The ballast shall produce positive lamp ignition over a voltage range not less than  $\pm 5$  percent of the nominal system voltage.

Operating characteristics shall produce output regulation not exceeding 35 percent. For this measure, regulation shall be defined as the ratio of the lamp watt difference between the upper and lower operating curves to the nominal lamp watts; with the lamp watt difference taken within the ANSI trapezoid parallel to the minimum lamp volt line. The ballast shall be designed to furnish proper electrical characteristics for starting and operating a high pressure sodium vapor lamp of the specified rating at ambient temperatures of  $-29^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ . The ballast windings shall be adequately impregnated and treated for protection against the entrance of moisture, insulated with Class H insulation, and able to withstand the NEMA standard dielectric test. The ballast shall include an electronic starting assembly.

The starter assembly shall be comprised of solid state devices capable of withstanding ambient temperatures of 85 °C. The starter shall provide timed pulsing with sufficient follow-through current to completely ionize and start all lamps. Minimum amplitude of the pulse shall be 2,500 V, with a width of 1 microsecond at 2,250 V, and shall be applied within 20 electrical degrees of the peak of the open circuit voltage wave with a repetition rate as recommended by the lamp manufacturer for the 60 cycle wave. The lamp peak pulse current shall be a minimum of 0.2 amperes. Proper ignition shall be provided over a range of input voltage from 200 to 244 V. The starter component shall be field replaceable and completely interchangeable with no adjustment necessary for proper operation. The starter component shall have push-on or crimped type electrical terminations to provide good electrical and mechanical integrity and ease of replacement. Terminal configuration shall preclude improper insertion of plug-in components. The starter circuit board shall be treated in an approved manner to provide a water and contaminant-resistant coating.

The ballast shall withstand a 2,500 V dielectric test between the core and windings without damage to the insulation. The ballast shall not subject the lamp to crest factor exceeding 1.8 and shall operate the lamp without affecting adversely the lamp life and performance.

Ballast losses, based on cold bench tests, shall not exceed 12 percent to a nominal 100 V lamp at the nominal input voltage for 200, 250 and 310 W lamps and 10 percent for 400 W lamps. Ballast losses shall be calculated based on input watts at nominal voltage and nominal lamp watts as follows:

$$\text{Percent Losses} = \frac{W_j - W_n}{W_n}$$

Where: =  $W_j$  - Input Watts at Input Voltage  
           =  $W_n$  - Nominal Lamp Watts

- c. High Pressure Sodium Regulator. The ballast shall be a high power factor magnetic regulator (lag type) ballast and, except as specified herein, shall be as specified for high pressure sodium reactor ballasts.

The ballast shall produce positive lamp ignition over a voltage range not less than  $\pm 10$  percent of nominal system voltage. Operating characteristics shall produce output regulation not exceeding 20 percent. Ballast losses shall not exceed 20 percent for a nominal 100 V, 400 W lamp and 25 for other sizes.

- d. Fluorescent, High Output. The ballast shall be mounted within the fixture and be designed to operate at 240 VAC, 60 Hz, with a high power factor. The ballast shall be capable of starting and operating

two F72T12 rapid start, high output, cool white fluorescent lamps at a 800 mA current and a temperature of -29 °C (-20 °F).

- e. Low Pressure Sodium. The ballast shall be suitable for use on a 240/480 volt, 60 Hz, single phase three wire electrical system. The ballast shall be designed for 240 V nominal voltage operation and be able to start the lamp and control its operation continuously over an ambient temperature range from -29 °C to +40 °C. The ballast may be magnetic, solid state or a hybrid of the two.

The ballast shall control the 240 V nominal voltage within  $\pm 10$  percent variation for the 55 W lamp. It shall regulate the output power to  $\pm 5$  percent for an input voltage fluctuation of  $\pm 10$  percent.

Total ballast losses shall not exceed 45 percent of nominal load for the 55 watt lamp.

The ballast shall withstand a 2,500 V dielectric test between the core and windings without damage to the insulation.

The ballast shall not subject the lamp to a crest factor exceeding 1.8 and shall operate the lamp without affecting adversely the lamp life and performance.

- (6) Photometric Performance. The luminaire photometric performance shall produce results equal to or better than those listed in the applicable Luminaire Performance Table or tables. Submittal information shall include computer calculations based on the controlling given conditions which demonstrate achievement of all listed performance requirements. The computer calculations shall be done according to I.E.S. recommendations and the submitted calculations shall include point-by-point illuminance, luminance and veiling luminance as well as listings of all indicated averages and ratios as applicable. The program used to perform the calculations shall be identified on the submittal. Rounding of calculations shall not be allowed.

In addition to computer printouts of photometric performance, submittal information shall include:

- a. Descriptive literature
- b. Isofootcandle chart of horizontal lux (footcandles)
- c. Utilization curve
- d. Isocandela diagram
- e. Luminaire classification per ANSI designation

- f. Candlepower values at every 2.5 degree intervals
- g. Candlepower tables are to be provided on 130 mm (5 1/4 in.) diskette in the I.E.S. format.

(7) Independent Testing. When specified, independent testing of luminaires shall be required. For each luminaire type to be so tested, one luminaire plus one additional luminaire for each 50 luminaires shall be tested.

The Contractor shall select one of the following options for the required testing with the Engineer's approval:

- a. Engineer Factory Selection for Independent Lab: The Contractor shall propose an independent test laboratory for approval by the Engineer. The selected luminaires shall be marked by the Engineer and shipped to the independent laboratory for tests.
- b. Engineer Witness of Independent Lab Test: The Engineer shall select, from the project luminaires at the manufacturer's facility or at the Contractor's storage facility, luminaires for testing by the independent laboratory.
- c. Independent Witness of Manufacturer Testing: The independent witness shall select from the project luminaires at the manufacturer's facility or at the Contractor's storage facility, the luminaires for testing. The Contractor shall propose a qualified independent agent, familiar with the luminaire requirements and test procedures, for approval by the Engineer, to witness the required tests as performed by the luminaire manufacturer.

In all cases, the selection of luminaires shall be a random selection from the entire completed lot of luminaires required for the contract. Selections from partial lots will not be allowed.

The selection of the testing option shall be presented with the information submitted for approval. The proposed independent laboratory or independent witness shall be included with that information.

The testing performed shall include photometric and electrical testing. Photometric testing shall be according to IES recommendations and as a minimum, shall yield an isofootcandle chart, with max candela point and half candela trace indicated, an isocandela diagram, maximum planned and maximum cone plots of candela, a candlepower table (House and street side), a coefficient of utilization chart, a luminous flux distribution table, and complete calculations based on specified requirements and test results.

Electrical testing shall conform to NEMA and ANSI standards and as a minimum, shall yield a complete check of wiring connections, a ballast



dielectric test, total ballast losses in watts and percent of input, a lamp volt-watt trace, regulation data, a starter test, lamp current crest factor, power factor (minimum over the design range of input voltage at nominal lamp voltage) and, a table of ballast characteristics showing input amperes, watts and power factor, output volts, amperes, watts and lamp crest factor as well as ballast losses over the range of values required to produce the lamp volt-watt trace.

The summary report and the test results shall be certified by the independent test laboratory or the independent witness, as applicable, and shall be sent by certified mail directly to the Engineer. A copy of this material shall be sent to the Contractor at the same time.

Should any of the tested luminaires of a given distribution type and wattage fail to satisfy the specifications and perform according to approved submittal information, the luminaire of that distribution type and wattage shall be unacceptable and be replaced by alternate equipment meeting the specifications with the submittal and testing process repeated in their entirety; or corrections made to achieve required performance. In the case of corrections, the Contractor shall advise the Engineer of corrections made and shall request a repeat of the specified testing and, if the corrections are deemed reasonable by the Engineer, the testing process shall be repeated. The number of luminaires to be tested shall be the same quantity as originally tested. Luminaires which are not modified or corrected shall not be retested without prior approval from the Engineer.

Coordination shall be the Contractor's responsibility. Failure to coordinate arrangements and notice shall not be grounds for additional compensation or extension of time.

Submittal information shall include a statement of intent to provide the testing as well as a request for approval of the chosen laboratory.

- (8) Finish. Luminaires supplied with weathering steel poles shall be furnished with a bronze baked acrylic enamel finish. When supplied with an aluminum or galvanized steel pole, the color shall be munsell grey. The luminaire shall match other pole types and finishes as approved by the Engineer.
- (b) Vibration Characteristics. Bridge mounted and high mast luminaires shall be vibration tested and pass ANSI C136.31 and be rated for "3G" peak acceleration. In order to be accepted the luminaire housing, hardware and each individual component shall pass this test with no noticeable damage and the unit must remain fully operational after testing.
- (c) Roadway Luminaire.
  - (1) Horizontal Mount.

- a. General. The effective projected area of the luminaire shall not exceed 0.149 sq m (1.6 sq ft).

The luminaire shall slip-fit on a 60 to 75 mm (2 3/8 to 3 in.) O.D. pipe arm, and shall have a barrier to limit the amount of insertion. It shall not be necessary to remove more than the cover, reflector, and refractor or lens to mount the luminaire.

The luminaire shall be provided with a leveling surface and shall have a four bolt anchoring/attachment means so as to be capable of being tilted by  $\pm 3$  degrees and rotated to any degree with respect to the supporting arm.

The luminaire shall have a built in device indicating the direction and amount of tilt over a range of zero to five degrees and shall be accurate to within 1/2 degree. The indication shall be clearly visible in daylight to an observer located a minimum of 16 m (50 ft) below the luminaire.

The light distribution shall be medium - cutoff Type III (M-C-III), as defined in the "American National Standard Practice of Roadway Lighting", ANSI-IES (RP-8) unless otherwise specified.

The beam of maximum candlepower for luminaires specified or shown to have "medium" distribution shall be at 70 degrees from horizontal  $\pm 2$  degrees. Submittal information shall identify this angle.

- b. Housing. The housing shall be made of cast aluminum or cast aluminum alloy. On aluminum alloys that darken due to atmospheric exposure, the finish shall be textured aluminum and shall be colored by painting with a suitable lacquer, enamel, or other paint. The paint shall be the manufacturer's standard gray. The external latches, nuts, screws, washers, pins and other parts shall be made of stainless steel or galvanized steel.
- c. Lens/Refractor. Luminaires shall have lenses made of crystal clear, impact and heat resistant flat glass. The lens shall be held in such a manner as to allow for its expansion and contraction. Where refractors are specifically indicated or permitted, they shall be prismatic impact and heat resistant glass.

(2) Multi Mount.

- a. General. The luminaire shall be a pole top, vertical slip fitter, single lamp fixture. The maximum weight of the luminaire shall be 45 kg (100 lb) and its effective projected area shall not exceed 0.36 sq m (3.85 sq ft).
- b. Housing. The housing of the luminaire shall be cast aluminum with a baked enamel finish. It shall consist of a main housing containing

the reflector and electrical equipment, and a refractor housing. The refractor housing shall be securely attached to the main housing and be readily removable for luminaire servicing.

- c. Mounting. The luminaire shall be equipped with a vertical slip-fitter and a leveling aiming adjustment assembly for rapid and versatile field installation. The slip-fitter shall accept 60 to 75 mm (2 3/8 to 3 in.) O.D. tenons. The assembly shall provide a horizontal leveling adjustment of  $\pm 15$  degrees about a standard luminaire axis position of 45 degrees.
- d. Alignment. To provide maximum illumination on the roadway, the Contractor shall calculate the proper vertical angle and orientation for each luminaire location. Subsequent vertical angle adjustments required from a final inspection shall be considered part of the pay item and additional compensation will not be allowed.

(3) Rectilinear.

- a. Housing. The luminaire housing shall be made of aluminum. The housing shall be die-cast aluminum or extruded aluminum. Any welds made to the housing shall be continuous. Seams shall be ground smooth without the use of fillers such as silicone or plastic materials. The housing shall be free of burrs and protrusions.
- b. Lens and Frame. The lens frame shall be held snugly in such a manner as to allow for its expansion and contraction. The lens shall be held within a metal frame which shall be mounted to the housing. The lens frame assembly shall hinge down for access to the internal components of the luminaire. The hinge arrangement may be heavy-duty pin-type hinges or other arrangements approved by the Engineer but the assembly shall assure that the lens frame will open for clear access to the inside of the luminaire and that easy positive alignment of the frame upon re-closing, without lifting an/or shifting or the frame, is assured. The lens frame shall be held closed by heavy-duty, captive, stainless steel quarter turn slot screw type fasteners conforming to the specifications for hardware.
- c. Optical Assembly. A glass reflector finish may be substituted in place of an oxide coating. The glass finish shall be chemically bonded to the reflector and shall be flexible, impact resistant, and heat resistant.

Segmented reflectors, if used, shall have extensive bracing and support of the reflective segment members to minimize the potential for accident bending of the segments during installation or maintenance.

(d) High Mast Luminaire.

- (1) General. The luminaire shall be designed and manufactured for high mast tower use. It shall be compatible for mounting heights in excess of 30 m (100 ft) with 130 km/h (80 mph) wind speeds and 167 km/h (104 mph) gusts. It shall be designed to withstand the physical stresses associated with such duty including shocks and vibrations.

- (2) Horizontal Mount.

- a. Housing. The luminaire housing shall be made of die cast aluminum with the top and sides continuous without seams or welds. The housing shall be free of burrs and protrusions.
- b. Hardware. All hardware shall be stainless steel or of other high-strength corrosion resistant material approved by the Engineer and shall be of extra heavy duty construction.

Fasteners such as quarter-turn clips shall be heavy spring loaded type with large, deep straight slot heads, complete with receptacle and shall conform to Military Specification MIL-F-5591. Other hardware shall conform to Military Specifications, wherever applicable.

All hardware shall be captive, not susceptible to falling from the luminaire during maintenance operations. This shall include lens/lens frame fasteners as well as hardware holding the removable ballast/electronic components in place.

- c. Lens and Lens Frame. The lens shall be made of crystal clear, impact and heat resistant glass which shall be flat or convex but convex lenses shall not be more than 95 mm (3 3/4 in.) convex from flat. The luminaire shall meet the cutoff and veiling luminaire (glare) criteria specified elsewhere herein regardless of the lens configuration.

The lens frame shall be held snugly yet in such a manner as to allow for its expansion and contraction. The lens shall be held within a metal frame which shall be mounted to the housing. The lens frame assembly shall hinge down for access to the internal components of the luminaire. The hinge arrangement shall be heavy-duty pin-type hinges or other arrangements approved by the Engineer. The assembly shall assure that the lens frame opens for clear access to the inside of the luminaire. There shall be positive alignment of the frame upon reclosing, such that no lifting and/or shifting of the frame occurs.

The lens frame shall be held closed by heavy-duty, captive, stainless steel quarter turn slot screw type fasteners conforming to the specifications for hardware, herein.

- d. Reflectors. The reflector shall be made of hydroformed aluminum. The reflecting surface shall have a specular finish and have a

dense protective coating or oxide not less than 0.012 mg/sq mm (7.5 mg/sq in.), applied by the anodic oxidation process. A glass reflector finish may be substituted in place of the above oxide coating. The glass finish shall be chemically bonded to the reflector and shall be flexible, impact resistant, and heat resistant.

The reflector and lamp socket assembly shall be capable of being rotated  $\pm 75$  degrees (150 degrees total) with respect to the mounting arm. Orientation shall be as directed by the Engineer.

The luminaire shall be equipped with identifying markings to indicate the mounted orientation. Luminaire installation shall include engraved banding of the mounting arms to designate proper orientation.

When the design of the luminaire is such that the reflector must be removed or disconnected to gain access to the ballast or when the reflector must be hinged open or otherwise moved to relamp the luminaire, the reflector shall remain captive to the luminaire and shall not interfere with the access required.

Removal of the reflector regardless of luminaire position, shall not require or invite handling of the essential reflective portion of the assembly. When required, the reflector shall be equipped with clearly identified handles, lifting tabs or the lid for reflector removal.

The reflector and the entire optical assembly shall not develop any discoloration over the normal life span of the luminaire.

- (3) Refractor Type Horizontal Mount. The optics shall be arranged so the pattern can be rotated 360 degrees around its vertical axis with a position indication. Maximum total utilization on the street side shall not be less than 42 percent.

For an open-bottom luminaire, the reflector shall be constructed of pressed, prismatic, annealed, borosilicate glass. The luminaire shall operate as an open-ventilated unit permitting free flow of air upward by chimney action through the optical assembly.

For an enclosed bottom luminaire, the reflector shall be of Alzak finished spun aluminum process with "flats" in the upper portion to redirect reflected light away from the arc tube of the lamp. The reflector assembly shall be enclosed and gasketed and shall include a filter to allow breathing. The bottom cover of the luminaire shall be made of clear, tempered, heat and shock-resistant glass, and shall be attached to the reflector housing by means of a hinged, gasketed door frame and five or more toggle latches. The socket mounting assembly shall have a provision of adjustment for the maximum candle-power in the field.

All hardware shall be made of stainless steel.

- (4) Multi-Mount Type. Multi-mount high mast luminaires shall be according to Article 1067.01(c)(2).

- (e) Underpass Luminaire

- (1) General. The underpass luminaire shall be suitable for lighting a roadway underpass at approximate mounting height of 4.5 m (15 ft) from a position suspended directly above roadway or attached to a wall or pier.

The luminaire shall provide the lighting distribution described, be optically sealed, mechanically strong and easy to maintain. The reflector, wiring terminals, and ballast components shall be readily accessible. When closed for operation, the optical assembly and the ballast assembly shall be sealed against the entry of moisture, dirt and insects. It shall not be necessary to remove more than the cover, reflector and lens to mount the luminaire.

The unit shall be heavy duty, suitable for highway use and shall have no indentations or crevices in which dirt, salt, or other corrosives may collect.

All removable components and hardware, except for the ballast tray, shall be held captive.

- (2) Low Pressure Sodium.

- a. Housing. The housing, ballast door, and lens frame shall be made of 0.076 mm (0.0299 in.) (22 gauge) minimum thickness stainless steel or heavy duty (NEMA) die cast aluminum. All seams shall be continuously welded with stainless steel welding wire. All internal and external hardware shall also be made of stainless steel, Type 304. All seams in the housing enclosure shall be constructed of the dutch-lip folding type and be welded by continuous welds. The lens frame of the stainless steel housing shall be sufficiently strong to hold the lens firmly in place. When closed, the frame shall be held securely in place with heavy duty quarter turn fasteners held captive in the frame and gasketed with neoprene washers or by heavy duty stainless steel latches acceptable to the Engineer. It should be possible to open and close the quarter turn fasteners/latches without the use of tools. The corners of lens frame shall be mitered and tack welded. When in open position, it shall be possible to unhinge and remove the frame for maintenance. There shall be a lead free hinge pin for easy rehinging of the frame and it shall be held captive via a chain or by other means approved by the Engineer.
    - b. Lens and Lens Frame. The lens shall be made of prismatic, crystal clear, impact and heat resistant borosilicate glass. Injection or vacuum molded acrylic or polycarbonate refractors or lenses shall be acceptable only when ultraviolet radiation is totally absent.

Acrylic or polycarbonate refractors or lenses shall be heat and impact resistant and shall not discolor. The lens shall be held in such a manner as to allow for its expansion and contraction, due to temperature variation.

The lens shall be held within a lens frame. The frame shall be sufficiently strong to hold the lens firmly in place. When closed, the frame shall be held securely in place with heavy duty quarter turn fasteners, held captive in the frame, which could be easily operated without the use of tools. When in open position, the frame shall unhinge and remove.

- c. Reflector. The reflector shall be of aluminum sheet of not less than 0.63 mm (0.025 in.) thickness. The reflector may have a specular finish with either an oxide or glass coating or it may have a baked white enamel finish.
- d. Gasketing. The junction between the lens frame and the housing, the ballast compartment door and the housing, and the lamp socket and reflector junction shall be sealed with a high temperature silicone rubber or dacron felt gasket. The gasket seal shall be waterproof. The junction between flexible conduit connections to the luminaire shall withstand entry of water when subjected to a water jet pressure of 207 kPa (30 psi), tested under laboratory conditions.
- e. Mounting Bracket. The luminaire mounting brackets shall be attached to the luminaire housing. The brackets shall allow the luminaire housing to be rotated  $\pm 30$  degrees in marked increments of five degrees. The brackets shall be made of 3.05 mm (11 gauge) minimum thickness stainless steel, attached rigidly to the housing in a manner satisfactory to the Engineer. The luminaire shall have an opening in the housing for installation (by others) of a 25 mm (1 in.) diameter flexible conduit.
- f. Testing. Submittal information shall include documentation of previous independent testing demonstrating compliance with these specifications, including water jet testing of the enclosure at not less than 14 kg (30 lb) of pressure for a duration of two minutes.
- g. Fusing. Each luminaire shall include a fuse, one for each phase conductor, in a vibration resistant screw-in fuseholder mounted inside the luminaire enclosure suitable for use in this application. Fusing shall be according to Article 1065.01.

### (3) High Pressure Sodium

- a. General. The Underpass luminaire shall be complete with all supports and hardware, identification bracket and decals, and appurtenant mounting accessories. The underpass luminaire shall be suitable for lighting a roadway underpass at approximate

mounting height of 4.5 m (15 ft) from a position suspended directly above roadway or attached to a wall or pier.

- b. **Stainless Steel Housing.** The stainless steel housing, and lens frame shall be made of 16 gauge minimum thickness stainless steel, Type 304. All internal and external hardware shall also be made of stainless steel. All seams in the housing enclosure shall be welded by continuous welds.
  1. **Lens and Lens Frame.** The lens shall be made of 19 tempered crystal clear borosilicate glass. The lens shall be held within a lens frame. The frame shall be sufficiently strong to hold the lens firmly in place. The frame shall not overlap the housing when closed. When closed, the frame shall be held securely in place with Engineer approved latches or heavy duty fasteners, held captive in the frame, which can be easily operated without the use of tools. When in the open position, the frame shall unhinge and be removable for maintenance and shall be held captive by a chain or other means approved by the Engineer. The lens frame shall be hinged with a continuous stainless steel piano type hinge or other hinge arrangement as approved by the Engineer.
  2. **Reflector.** The reflector shall be hydroformed specular aluminum type. The reflector shall have an anodic coating not less than 0.007 mg/sq mm (4.5 mg/sq in.) and sealed in a hot water rinse having a closely controlled ph factor.
  3. **Mounting Bracket.** Four luminaire mounting brackets fabricated from 3.05 mm (11 gauge) stainless steel shall be welded to the luminaire housing. The luminaire shall have an opening in the housing for installation (by others) of a 25.4 mm (1 in.) diameter flexible conduit.
  4. **Testing and Fusing.** Testing and fusing shall be according to Article 1067.01(a)(7) and 1065.01.
- c. **Cast Aluminum Housing.** The luminaire housing shall be made of heavy duty die cast aluminum with the back and sides continuous without seams or welds. The housing shall be free of burrs and protrusions. The lens frame shall be die cast aluminum of sufficient structural strength to hold the refractor firmly in place. The door shall be attached to the housing with stainless steel hinges and hardware. It shall be secured in the closed position by two spring loaded toggle action latches or two captive stainless steel threaded fasteners.
  1. **Refractor.** The refractor shall be made of molded prismatic thermal shock resistant borosilicate glass.



2. Reflector. The reflector shall be hydroformed, specular aluminum with bonded finish for corrosion resistance durability and ease of cleaning.

Lamp Holder. Lamp holder shall be according to Article 1067.01(a)1.

Ballast. The ballast shall be according to Article 1067.01(a)5.

3. Mounting. The mounting brackets and rods shall be galvanized according to AASHTO M111. All other hardware shall be stainless steel. The luminaire shall have a conduit opening in the housing for installing a 3/4 in. diameter flexible conduit.

(f) Sign Luminaire

- (1) General. The luminaire shall be suitable for lighting expressway guide signs. The fixture shall be UL Listed for wet locations.

(2) Fluorescent.

- a. Housing. The outer housing shall be constructed from 1.6 mm (0.064 in.) thick 3003-H14 aluminum. The housing shall have an extruded aluminum hinge, one half of which is an integral part of the housing.
- b. Lens and Frame. The lens frame shall be made of extruded aluminum and have a continuous extruded neoprene gasket seal to insure weatherproofing. The frame shall have a concealed retaining latch which locks the door open for servicing and shall include a safety chain. The frame shall have spring loaded toggle action latches. The lens shall be made of clear 3 mm (0.125 in.) thick acrylic.
- c. Lamp Holders. The lamp holders shall be end mounted, spring loaded, self-sealing, and self-aligning.
- d. Reflector. The reflector shall be made of 0.5 mm (0.020 in.) minimum thickness specular aluminum.
- e. Wiring. All wiring connections in the fixture shall terminate on molded phenolic, barriers type, heavy duty, terminal blocks rated for a maximum current of 30 amperes and maximum voltage of 3,300 volts. The terminal block shall accommodate No. 10 AWG wire and shall be legibly color marked to suit the ballast wire colors. All wiring, terminal blocks, and ballast shall be fully enclosed within the fixture so none of the above parts are exposed when relamping.
- f. Testing and Fusing. Testing and fusing shall be according to Article 1067.01(a)(7) and 1065.01.

## (3) High Pressure Sodium.

- a. **Housing.** The housing shall be heavy duty die cast aluminum which shall support and enclose the reflector, electrical assembly, and 30 mm (1 1/4 in.) conduit supports and shall interact with the hingeable door to provide a watertight lamp environment. A single piece weather resistant gasket shall seal the door to the housing when stainless steel door latch bolts are secured. The integrally cast hinge shall allow the door to stand open to allow full access to the electrical components. All hardware shall be stainless steel. All die cast aluminum surfaces shall be finished with a heavy duty coat of gray acrylic enamel. Housing shall be provided with pads for three point surface mounting.
- b. **Lens and Frame.** The lens shall be shock resistant tempered glass secured in a heavy duty die cast aluminum frame with self-supporting hinges and an integral glare shield.
- c. **The Reflector.** The reflector shall be hydro formed aluminum with a bonded finish for corrosion resistance, durability and ease of cleaning.
- d. **Wiring.** All electrical components shall be prewired and tested after assembly. Ballast components shall be heat sunk against the cast aluminum housing.
- e. **Performance.** The optical assembly shall provide an illumination level on the sign face that does not exceed a gradient ratio of 2.0.

**1067.02 Lamps.** The lamps in all luminaires and traffic signal heads shall conform to ANSI requirements.

## (a) High Pressure Sodium Vapor Lamps.

- (1) The lamps shall be of the clear type and shall have a color of 1050 to 2100 °Kelvin.
- (2) At half of the average rated lamp life, the mean output lumens shall not be less than 90 percent of initial lumen output.
- (3) High pressure sodium lamps shall be non-cycling type and suitable for any burning position.
- (4) High pressure sodium lamps shall meet or exceed the following characteristics:

<u>Lamp Wattage</u> (Watts)	<u>Rated Life</u> (Hours)	<u>Initial Lumen Output</u> (Lumens)	<u>Lamp Voltage</u> (Volts)
35	16,000	2,250	52
50	24,000	4,000	52
70	24,000	5,800	52
100	24,000	9,500	55
150	24,000	15,000	100
200	24,000	22,000	100
250	24,000	27,500	100
310	24,000	37,000	100
400	24,000	50,000	100
750	24,000	110,000	120
1000	24,000	140,000	250

## (b) Low Pressure Sodium Vapor Lamps.

- (1) Lamps shall be of the clear type with an internal coating reflect infrared radiation back to the discharge tube.
- (2) Mean lumen output shall be not less than initial lumen output.
- (3) Lamps shall have insulating shields at the ends of arc tubes to control lamp wattage rise and improve lamp life characteristics.
- (4) Low pressure sodium lamps shall meet or exceed the following characteristics:

<u>Lamp Wattage</u> (Watts)	<u>Rated Life</u> (Hours)	<u>Initial Lumen Output</u> (Lumens)
18	14,000	1,800
35	18,000	4,800
55	18,000	8,000
90	18,000	13,500
135	18,000	22,500
180	18,000	33,000

## (c) Metal Halide Lamps.

- (1) The lamps shall be of the clear type and shall have a color of 3200 to 3800 °Kelvin.
- (2) At 40 percent of the average rated lamp life, the mean lumens shall not be less than 80 percent of initial lumen output.
- (3) Lamps shall be suitable for the burning position orientation of the luminaires for which they are supplied.

(4) Metal halide lamps shall meet or exceed the following characteristics:

<u>Lamp Wattage</u> (Watts)	<u>Rated Life</u> (Hours)	<u>Initial Lumen Output</u> (Lumens)
70	7,500	5,500
100	15,000	9,000
150	15,000	13,000
175 Vertical	10,000	16,000
175 Horizontal	6,000	12,000
250	10,000	20,500
400	20,000	40,000
1,000 Vertical	12,000	110,000
1,000 Horizontal	12,000	107,800

- (d) Fluorescent. Fluorescent lamps for sign lighting shall be 800 ma, rapid start, high output, cool white, Type F72T12/CW/HO with an average rated life of 12,000 hours and a mean lumen output of 5,520 lumens. All fluorescent lamps shall be capable of starting and operating at a minimum temperature of -30 °C (-20 °F).
- (e) Incandescent. Incandescent lamps shall be a type having an average rated life of 8,000 hours. A 135 watt lamp shall produce 1,750 lumens and 54 watt lamps shall produce 595 lumens. Other lamps shall be of the extended service type of the wattage indicated.

**1067.03 Navigation Obstruction Warning Luminaires**

- (a) Waterway Obstruction Warning Luminaire. The fresnel lens shall be one piece, precision molded, color impregnated tempered glass. Astragals shall be oriented so as to minimize their impact on the light beam at all viewing angles.
- (1) General. The luminaire shall be optically sealed, mechanically strong, and easy to maintain. The luminaire shall meet all requirements set forth by the United States Coast Guard. The lamp cavities shall be either watertight, or they shall be weatherproof and bugproof. The lamp shall be easily accessible for relamping through gasketed doors which are held captive by means of hinges or a brass chain.
- (2) Dual Cavity Luminaire with Transfer Relay. The luminaire shall have two separate lamp cavities each equipped with fresnel lens and spring mounted, vibration resistant, medium, 600 watt, 250 volts, porcelain socket. The navigation light shall have two 120 volt, 75 watt, 20,000 hour life, clear long life incandescent lamps. The auxiliary lamp transfer relay shall be enclosed in its own cast aluminum housing with gasketed weather-proof cover mounted as shown on the plans. It shall be suitable for mounting on the navigational luminaire function with a line variation of 120 VAC ± 20 percent and shall be protected from shock, vibration and humidity.

The navigation light shall have a cast bronze, marine grade aluminum, or brass body and be Coast Guard approved. Nuts, bolts, thumb screws, hardware, thread rods, pipe, hanger, and mounting bases which are exterior, shall be stainless steel (300 series) or bronze. Hardware on the interior of the lamp cavity shall be stainless steel or bronze.

- (3) Luminaire with Automatic Lamp Changer. The luminaire shall be equipped with a single, six-place lampchanger which detects a lamp failure and automatically places a new lamp at the lens focal point with an accuracy of 13 mm (0.5 in.) of true center.

The lampchanger housing and lamp holder shall be accurately molded of corrosion resistant materials to assure long, trouble free operation. Gold plated or other Engineer approved contacts shall be supplied standard on all lampchangers. The lampchanger shall meet or exceed the requirements of the U.S. Coast Guard Specification #195, including vibration test at 5G's, shock test at 20G's, salt spray and immersion. Lamp changing actuation shall be accomplished by a motorized or spring driven, solenoid activated mechanism.

The lampchanger shall have solid state circuitry rated at 4 A to assure long life and dependable operation. Terminal blocks shall be color coded. The lampchanger shall operate dependably on a minimum of 8 V and a maximum of 14 V, AC or DC, without modification. A 120 V step-down transformer shall be furnished to provide the 12 V lamp source and shall be housed within the luminaire. The lamp shall be 12 V, 0.55 A, 4,000 hour life minimum, clear S-8 marine signal lamps with a prefocused base.

- (4) LED Luminaire. An LED light source shall produce the same candela output as a comparable incandescent luminaire. LED life for the optic shall exceed 30,000 hours and the end of life output shall not depreciate below 70 percent of its initial rating or a level established by the U.S. Coast Guard, whichever is greater. The LED array shall be mounted on a shock and vibration isolator in the center of the lens focal point. A 120 V step-down transformer and rectifier shall be furnished in the luminaire to provide an appropriate current-limited DC voltage source to the LED array regardless of its color (white, red, or green).

- (b) Aviation Obstruction Warning Luminaire. Luminaires shall be 300 mm (12 in.) beacon type and constructed to meet all FCC and FAA requirements for continuous service under all weather conditions. The housing shall be constructed of heavy cast aluminum with cast aluminum globe support rings to accommodate two 360 degree red fresnel lenses or red color filters. The lamp cavities shall be vented weather, and insect proof. The light shall have two 120 V, 620 W, 3,000 hour life, long life incandescent lamps. Each luminaire shall be operated by a beacon flasher conforming to FAA regulations without field adjustment. It shall be a two circuit control rated for 2.0 kW maximum, continuous tungsten load up to 55 °C (131 °F) ambient air temperature at 120 V. Flash rate shall be 30 FPM 2/3 on, 1/3 off duty cycle.

Normally closed solid state relay configuration shall prove a "lights on" condition for fail safe operation. It shall be equipped with built-in surge and transient protection and furnished in a NEMA-3 enclosure.

## **SECTION 1068. CONTROLLER**

### **1068.01 Lighting Controller.**

- (a) General. The completed controller shall be an Industrial Control Panel under UL 508.
- (b) Enclosures.
  - (1) Single Door Enclosure.
    - a. Cabinet. The cabinet shall be single door design, fabricated from 3 mm (0.125 in.) thick Type 5052-H32 aluminum or AISI 304 stainless steel. The cabinet door frame shall be double flanged on all four sides. All external hardware shall be stainless steel. The cabinet shall have a NEMA 3R rating. Where no dimensions are indicated, the cabinet shall be sized to adequately house all required components with ample room for arrangement and termination of wiring. A 60 percent fill capacity shall be the design guideline.
    - b. Door. The door shall be constructed from the same material and thickness as the cabinet. The door except for pedestal, pole or wall mounted cabinets shall be equipped with a three point latching mechanism with nylon rollers at the top and bottom. The door handle shall be stainless steel and shall have a minimum diameter of 13 mm (1/2 in.) and have a padlock provision. The door shall be sealed with a neoprene gasket. The door hinge shall be a heavy gauge continuous hinge with a 5 mm (1/4 in.) diameter stainless steel hinge pin. The hinge shall be secured with stainless steel carriage bolts and stainless steel nuts and locknuts. A linkage-arm system, of simple construction, shall be attached to the cabinet doors to secure them in a wide open position to insure safety during field operations. The door for pedestal, pole or wall mounted cabinets shall be furnished with a rain and ice resistant standard traffic signal lock and two keys.
    - c. Vent. The cabinet shall be equipped with a vent on top, designed to exclude moisture, dirt, and insects.
    - d. Post Top Mounting. The cabinet shall be mounted a top a 100 mm (4 in.) rigid aluminum schedule 40 conduit stem anchored to a cast aluminum pedestal base constructed of ASTM B26 or B108 A444-T4, A356.0-T61, or 356-T6 cast aluminum with an access handhole cover. The stem and base shall be painted as specified for the

cabinet. When post mounted, the cabinet shall have a stiffener plate bolted to the bottom of the enclosure.

- e. Base Mounting. Where indicated, the cabinet shall be mounted atop an enclosure base constructed from the same materials as the cabinet and of the same cross section as the cabinet. When specified, a steel transformer base shall be used for the enclosure base. When transformer base mounted, the cabinet shall have a stiffener plate bolted to the bottom of the enclosure. The transformer base shall be a non-breakaway base of a height and dimension as approved by the Engineer. The base extension shall be painted as specified for the cabinet. Where indicated, the foundation shall extend 300 mm (12 in.) above the surrounding grade to provide additional base extension.
- f. Work Pad. Except where the cabinet is facing a sidewalk, a poured, 100 mm (4 in.) thick concrete pad, not less than 1.2 m (48 in.) square shall be provided in front of the cabinet.

(2) Double Door Enclosure.

- a. Cabinet. The cabinet shall be of the dimensions shown on the plans and fabricated from 3 mm (1/8 in.) thick aluminum alloy No. 3003-H14. The cabinet shall comply with ANSI C33.71 and UL 50 and be reinforced with aluminum angles.
- b. Doors. The doors shall have stainless steel hinges. The door handle shall be stainless steel, a minimum diameter of 13 mm (1/2 in.) and be furnished with a rain and ice resistant lock. The doors shall be gasketed to exclude the entry of moisture, dirt, and insects. A linkage-arm system, of simple construction, shall be attached to the cabinet doors to allow securing in a wide open position during field operations.
- c. Insulation. When specified, the interior compartment shall be insulated on the inside of the sides, back, top, bottom, and inside of the doors with 25 mm (1 in.) thick polyisocyanurate rigid foam insulation board. The foam board shall have foil facers on each side. The side facing the interior of the cabinet shall have a white tinted foil facer with a satin finish. The insulation shall have a minimum aged thermal resistance (R-value) of 8 at a 4 °C (40 °F) mean temperature. The insulation shall comply with Federal Specification HH-I-1972/1, Class 2.
- d. Mounting. The cabinet shall be mounted as indicated on the plans.
- e. Work Pad. The working pad shall be according to Article 1068.01(b)(1)f above.

- (3) Wall Mount Enclosure. A wall mounted cabinet shall be according to Article 1068.01(b)(1) except when a stainless steel cabinet is specified the following requirements shall be met.
- a. Cabinet. The cabinet shall be a wall mounted type, NEMA 4X, not less than 14 gauge Type 304 stainless steel of the dimensions shown on the plans. The cabinet shall be sized to adequately house all required components with ample room for arrangement and termination of wiring. All seams shall be continuously welded with stainless steel weld wire.
  - b. Door. The front of the cabinet shall have a hinged stainless steel door equipped with a handle and latching device suitable for installing a padlock. The door shall be gasketed to exclude the entry of moisture, dirt, and insects. The cabinet door shall be made of not less than 14 gauge stainless steel, Type 304. A print pocket shall be attached to the inside of the door. The enclosure shall have a continuous stainless steel hinge welded to the door and to the enclosure. The door shall be held closed by means of captive clamps fabricated from 12 gauge stainless steel and held in place with stainless steel hex head bolts. The clamps are to incorporate a depth stop to insure uniform sealing pressure at all clamp points.
  - c. Finish. The enclosure shall be finished to a #3 polish. Painting of the stainless steel enclosure will not be required.

(c) Finish.

- (1) Unfinished Enclosures. Stainless steel enclosures shall not be painted.
- (2) Finished Enclosures. All aluminum enclosures shall be finished.

The cabinet shall be cleaned before painting inside and outside with oxalic acid for five to ten minutes, or as otherwise recommended by the paint manufacturer and approved by the Engineer, to etch the metal surfaces.

The cabinet shall then receive two sprayed coats of white polyamide epoxy primer with a corrosion inhibitor applied inside and outside to all surfaces. The primer shall have a solids content, by volume of not less than 65 percent and each coat shall be applied to a thickness of 0.076 to 0.125 mm (3 to 5 mils).

All surfaces, interior and exterior, shall receive one final coat of silicone alkyd enamel paint. The finish paint shall have a solids content, by volume, of not less than 53 percent, and shall be applied to a thickness of 0.038 to 0.064 mm (1.5 to 2.5 mils).

The color of the finish paint shall be ANSI Standard No. 70 Sky Gray or as specified by the Engineer.



The finish shall be applied according to the paint manufacturer's recommendations and the manufacturer shall certify, in writing, to the Department, that the finish has been applied properly.

Submittal data submitted for approval shall address the requirement for the paint manufacturer's certification and shall include a standard, single source paint warranty by the paint manufacturer of the controller manufacturer to the Department.

- (d) Identification. The cabinet door shall have a stainless steel name plate of the dimensions and engraving indicated on the plans.

- (e) Control Components.

- (1) Time Switch. When specified, each controller shall have an electric time switch for automatic control of highway lighting circuits operating on a daily schedule having a fixed relation to sunrise and sunset. Turn-on and Turn-off times shall be adjustable  $\pm 45$  minutes from sunrise and sunset. All settings shall be field adjustable without special tools. Complete installation instructions, details on wiring connections, and information on time setting, manual operation, and necessary adjustments shall be furnished with each time switch.

The time switch shall be a microprocessor-based two channel controller with astronomic functions on both channels. The latitude shall be adjustable from ten to 60 degrees in the Northern hemisphere. Latitude changes shall be user setable without the use of special tools.

The time switch shall be programmable in an AM/PM format, with a resolution of one minute or better. The time switch shall automatically adjust for daylight saving time and have automatic leap year correction and operate on 240 V AC without the use of an additional transformer.

A battery backup shall be integral with the controller and shall use a nickel-cadmium battery. The battery backup shall provide power to the controller memory for a minimum of 72 hours in the event of power failures.

The published operating temperature range of the time switch shall be from -30 °C to 70 °C (86 °F to 158 °F).

The time switch output relay contacts shall be rated sufficiently to handle the inrush current of two 200 A contactors. The time switch shall have a NEMA Type 1 enclosure as a minimum. The time switch programming instructions shall be moisture proof and permanently affixed to the time switch or as otherwise approved by the Engineer.

- (2) Photocell.

- a. General. The photocell shall consist of a metal electrode, molecularly bonded to a ceramic wafer, and coated with cadmium-

sulfide. The photo cell shall be highly corrosion resistant without "Plastic dipping" with a nominal 484 sq mm (0.75 sq in.) in surface area. Color response of the cell shall be such that a maximum sensitivity is in the blue-green portion of the color spectrum.

- b. Switching Relay. The "On-Off" switching operations shall be accomplished by a normally closed contact which will be operated by means of an electro-magnetic relay. The response time shall be less than one second time delay for turn-on and three to thirty seconds time delay to prevent the "Turn-off" due to the light flashes of less than 108 lux (10 foot candles). Photocell shall be capable of less than one second time delay for both turn-on and turn-off when tested in full daylight. In the event of a circuitry failure, the lights will be turned on, or remain on.
  - c. Surge Arrester. Overvoltage protection shall be provided for the control components and the load circuit by the means of an expulsion type surge arrester capable of passing the surge outlined in ANSI C136.10 except follow current is 10,000 A.
  - d. Chassis and Enclosure. The base of the unit shall be manufactured on a 75 mm (3 in.) wide, solid thermoset phenolic base. The bottom of the base shall have an integral, locking type, brass three prong plug according to NEMA specification SH16-1962. The gasket shall be of a cross-linked polyethylene to assure moisture proof seal to the luminaire socket.
  - e. Electrical. The control must be able to operate over the range of 105-305 V, 60 Hz AC. Its direct load rating shall be 1000 W Incandescent load and 1800 VA Mercury Vapor, High Pressure Sodium or other H.I.D. load.
  - f. Environmental. The control shall be stable and reliable over an operating temperature range of -55 °C (-65 °F) to 70 °C (158 °F).
  - g. Highway Lighting Operating Levels. Each control furnished shall be calibrated for a "Turn-on" setting of 5.4 to 22.5 lux (0.5 to 2.1 ft candles) of natural illumination and the "Turn-off" setting shall not exceed four times the "Turn-on" setting.
  - h. Navigation and Aviation Operating Levels. Each photocell furnished for navigation or aviation obstruction lighting control shall be calibrated for a "turn on" setting of 350 lux (35 foot candles) and "turn off" shall occur at 520 lux (52 foot candles) of natural illumination or according to the latest FAA and U.S. Coast Guard requirements.
- (3) Circuit Breakers. All feeders, branch circuits, and auxiliary and control circuits shall have overcurrent protection. The overcurrent protection shall be by means of circuit breakers.

Circuit breakers shall be standard UL listed molded case, thermal-magnetic bolt-on type circuit breakers with trip free indicating handles.

240 V circuit breakers shall have a UL listed interrupting rating of not less than 10,000 rms symmetrical amperes at rated circuit voltage for which the breaker is applied. 480 V applications shall have a UL listed interrupting rating of not less than 14,000 rms symmetrical amperes at rated circuit voltage.

Multi-pole circuit breakers larger than 100 A size shall have adjustable magnetic trip settings.

The number of branch circuit breakers shall be as indicated on the Control Cabinet detail drawing or as indicated in the lighting system wiring diagram which ever is greater plus two spare circuit breakers.

- (4) Contactors. Contactors shall be electrically operated, electrically or mechanically held, as specified, with the number of poles required for the service and with operating coil voltage as indicated. Ampere rating of contactors shall be not less than required for the duty shown and shall otherwise be rated as indicated.

Contactors shall be complete with a non-conducting inorganic, non-asbestos subpanel for mounting.

Electrically held contactors shall be used unless mechanically held contactors are specified. Electrically held contactors shall be NEMA, size 3, 2 pole, 60 Hz, 600 V, open panel mount type, normally open and electrically held and UL labeled.

Mechanically held contactors shall be complete with coil clearing contacts to interrupt current through the coil once the contactor is held in position.

The main contactor contacts shall be the double break, silver to silver type. They shall be spring loaded and provide a wiping action when opening and closing. The contacts shall be renewable from the front panel, self aligning, and protected by auxiliary arcing contacts.

The line and load terminals shall be pressure type terminals of copper construction and of the proper size for the ampere rating of the contactor.

A lever for manual operation shall be incorporated in the mechanically held contactor. Protection from accidental contact with current carrying parts when operating the contactor manually shall be provided.

The contactor operating coil shall operate at phase to neutral voltage. Single phase contactors shall be two pole devices with continuous rating for the amperage selected per pole.

Open and closed positions for mechanically held contactors shall be clearly indicated and labeled in permanent manner as approved by the Engineer.

- (5) Auto/Manual Switches for Mechanically Held Contactors. The cabinet shall be equipped with automatic and manual operating controls via two, single pole double throw switches, one being a maintained-contact manual-automatic selector switch and one being a momentary-contact manual on-off switch with a center rest position. Both switches shall be premium specification grade, rated for the applied duty but not less than 20 A at 240 V and each shall be mounted in a 100 mm (4 in.) square box with cover.

Selector Switch for Electrically Held Contactors. The selector switch shall have a glove-hand operating handle and industrial duty rotating mechanism. Contacts shall be rated 10 A make/break and continuous at 60 Hz, 600 V. The switch position shall be designated by a permanent name plate of metal or rigid laminated plastic. Switch shall be UL listed.

The control circuit shall have overcurrent protection as indicated and as required by NEC requirements.

- (6) Ground & Neutral Bus Bars. Separate ground and neutral bus bars shall be provided. The ground bus bar shall be copper, mounted on the equipment panel, fitted with 22 connectors of the type shown on the plans, as a minimum. The neutral bar shall be similar. The heads of connector screws shall be painted white for neutral bar connectors and green for ground bar connectors.
- (7) Interior Lighting and Receptacle. When specified, the cabinet shall have an auxiliary device circuit at 120 V single phase to supply a convenience receptacle and cabinet light. Where 120 V is not available directly from the service voltage, an outdoor dry type step-down transformer not less than 1 KVA shall be provided. It shall be according to Article 1068.02.

The auxiliary circuit, including transformer primary and secondary, shall have overcurrent protection according to NEC requirements.

The interior, 60 W incandescent lighting fixture of the enclosed-and-gasketed type, shall be switched from a single pole, single throw, 20 A switch. The switch shall be premium specification grade in a suitable 100 mm (4 in.) box with a cover.

A 20 A duplex receptacle, ground fault interrupting, premium specification grade shall be furnished in a 100 mm (4 in.) square box with cover, for 120 V auxiliary use.

- (8) Surge Arrester. The control circuit in the cabinet shall be protected by a surge arrester meeting the requirements of Article 1065.02.
- (f) Wiring and Identification. Power wiring within the cabinet shall be of the size specified for the corresponding service conductors and branch circuits and shall be rated RHH/RHW, 600 V.

Control and auxiliary circuit wiring shall be rated RHH/RHW or MTW with jacket, 600 V.

All power and control wiring shall be stranded copper. When specified all wiring shall be tagged with self-sticking cable markers. When the contract drawings do not specifically indicate assigned wire designations, the manufacturer shall assign wire designations and indicate them on the shop drawings.

All switches, controls and the like shall be identified both as to function and position (as applicable) by means of engraved two color nameplates attached with screws, or where nameplate are not possible in the judgement of the Engineer, by the use of cloth-backed adhesive labels as approved by the Engineer.

The cabinet with all of its electrical components and parts shall be assembled in a neat orderly fashion. All of the electrical cables shall be installed in a trim, neat, professional manner. The cables shall be trained in straight horizontal and vertical directions and be parallel, next to, and adjacent to other cables whenever possible.

**1068.02 Transformer, General Purpose.** The transformer shall be dry type and weatherproof so that it may be installed indoors or outdoors without additional housing. It shall have an enclosure for splices with provisions for weather tight conduit connections.

The transformer shall have four taps on the primary side, one at 2 1/2 percent, one at 5 percent, one at 7 1/2 percent and one at ten percent below rated voltage.

Insulation shall be Class F or Class H. The transformer shall meet the applicable ASA and IEEE standards.

Mounting and back plates shall be of Aluminum Alloy 2024, 3003 or 6061. Bolts, nuts and washers shall be of Series 300 stainless steel. Bolts shall have hexheads. Nuts shall be hexagon and self locking. Washers shall be of the flat type.

**1068.03 Navigation Obstruction Lighting Controller.** The completed controller shall be an Industrial Control Panel under UL 508 conforming to Article 1068.01 except that the control circuit shall have dual control components where highway lighting is operated out of the same controller as navigation lighting. The control circuit shall be as detailed in the plans and approved by the Engineer.

Each photocell furnished for navigation or aviation obstruction lighting control shall be calibrated according to Article 1068.01 (e) (2) h.

**SECTION 1069. POLE AND TOWER****1069.01 Light Poles.****(a) General.**

- (1) Wind Loading and Vibration. The detailed design and fabrication of the pole shaft and of the arms shall be according to AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals" current at the time the project is advertised.

There shall be no vibrations in the shaft or arm(s) under moderate wind pressure, where damage may result to the luminaire(s) and/or its component parts, and/or the arm(s). A dampening device, as an integral part of the shaft, shall be installed in the shaft to alleviate such excessive vibrations. The proposed vibration dampening device shall be submitted for the Engineer's approval.

Each pole shall have the manufacturer, lot number, and date of manufacture permanently stamped on the top of the base plate or other location approved by the Engineer.

- (2) Shipping. The shafts shall be shipped in bundles without any wrapping on the individual shafts or the entire bundle. Appropriate bundling materials shall be used to make a rigid, long lasting bundle capable of being handled, shipped and stored without shifting or breaking of contents.

**(b) Aluminum Pole.**

- (1) General. All aluminum poles shall have a satin ground finish, 100 grit or finer. All exposed surfaces of the shaft shall be of a smooth, even texture, free from marks and imperfections. Aluminum tubing shall be according to ASTM B 210M (B 210), Alloy 6063. Tempers selected shall depend on forming practices of the pole manufacturer to satisfy the following stress requirements induced by wind and fatigue. The shaft shall be spun drawn to a smooth, circular, seamless taper.

The pole shall be designed and manufactured to withstand loadings of up to and including a 34 kg (75 lb) luminaire having an effective projected area of 0.15 sq m (1.6 sq ft) on a single 4.5 m (15 ft) arm, and withstand loadings of up to and including the same luminaire on each of two 3.6 m (12 ft) arms (twin) oriented at any angle from 45 to 180 degrees apart. These loading requirements shall also include all luminaire and arm combinations possible for the given pole height, up to and including the limits given. Information submitted for approval shall document satisfaction of this requirement.

Reinforcing sleeves shall not be used without written approval by the Engineer. Minimum shaft wall thickness shall be achieved without the use of reinforcing sleeves.

Anchor rod covers shall be fastened to the base with 6 mm (1/4 in.) 20 threaded stainless steel hex-head screws coated with anti-sieze compound and the holes for the screws shall be tapped to match the screws. The anchor rod covers shall be made from aluminum, according to ASTM B 108, S5A-F, or B 26, SG70A and fit tightly to the pole base so as to prevent rodent entry. A non-metallic anchor rod cover used in high vandalism areas must be approved by the Engineer.

The pole shall be coordinated with all luminaires to be free of susceptibility to harmful harmonics and vibrations. The pole shall incorporate an internal vibration damper.

All hardware shall be anodized aluminum according to the ASTM B 211, 2024 T4, or 300 series stainless steel.

Tenon top poles supplied for multi-mount luminaires shall be furnished with a 75 mm (3 in.) O.D. X 150 mm (6 in.) long tenon.

(2) Mast Arm Style.

- a. General. The indicated mounting height shall be taken from the bottom of the pole shaft base plate and shall be obtained with a nominal mast arm rise of 865 mm (34 in.) as specified.
- b. Mast Arm. Top members of the arms shall have raceway openings extending through the bracket. Raceway openings shall be free of burrs and rough edges that may be injurious to the wires.

Exterior surfaces of the truss arms shall be free of all protuberances, dents, cracks, or other imperfections. The rise of the truss arm, shall be a nominal 865 mm (34 in.). The truss arm shall be made of aluminum alloy tube, round, seamless, according to ASTM B 221 and 6063 T6.

The truss arms shall be supplied with fabricated aluminum brackets welded to the arms. All welds shall be heat treated after welding. The fastening of the arms to the shaft shall be clamp type bracket with stainless steel bolts, nuts, and lockwashers.

c. Shaft.

Poles with mounting heights of 10.6 m (35 ft) or less shall have a single piece shaft with a 200 mm (8 in.) outside bottom diameter tapering to a 114 mm (4.5 in.) outside top diameter. The shafts shall be designed to accommodate Article 1069.01(a)(1) and (b)(1) loading with a minimum wall thickness of 5.6 mm (0.219 in.). The

wall thickness shall be increased as necessary to satisfy the design loading requirements.

Poles with mounting heights greater than 10.6 m (35 ft) but less than 15.2 m (50 ft) shall have a single piece shaft with a 250 mm (10 in.) outside bottom diameter tapering to 150 mm (6 in.) outside top diameter. Poles with mounting heights of 15.2 m (50 ft) or greater shall have a 250 mm (10 in.) outside bottom diameter tapering to 150 mm (6 in.) outside top diameter. Poles with mounting heights of 12 m (40 ft) or greater may have a two piece shaft.

The shafts shall have a minimum wall thickness of 6 mm (0.250 in.). The wall thickness shall be increased as necessary to satisfy the design loading requirements.

The bottom portion of the shaft shall be fitted with a base. The base shall be a permanent mold casting of aluminum alloy conforming to Aluminum Association designations 356.0 or A356.0, with final temper T6 of T61. The base shall be welded to the shaft by the inert gas shielded arc method. All welds shall be free from cracks and pores. All shafts with base plates shall be heat treated after welding. The base shall be equipped with anchor rod covers. Anchor rod slots shall be provided in the base to accommodate the required bolt circle diameter. Poles for mounting heights of 10.6 m (35 ft) or less shall have 290 mm (11 1/2 in.) bolt circles and poles for mounting heights greater than 10.6 m (35 ft) shall have 375 mm (15 in.) bolt circles. The size of the slots shall be 30 x 50 mm (1 1/4 x 2 in.) as detailed on the pole drawing.

- d. Handhole. The pole shall have an oval shaped opening in the side of the shaft. The centerline of the handhole shall be 450 mm (18 in.) from the bottom of the shaft. The handhole shall be 100 x 200 mm (4 x 8 in.) in size with the 200 mm (8 in.) dimension being situated vertically and in the same plane as any one of the sides of the base. The opening in the shaft shall be reinforced with a handhole frame situated on the inside of the shaft and welded to the shaft. A 13 mm (1/2 in.) tapped hole shall be provided in the frame for attaching a mechanical grounding connector. The handhole cover shall be fastened to the frame with 6 mm (1/4 in.) 20 size stainless steel hex-head screws coated with anti-sieze compound and the holes for the screws shall be tapped to match the screws. The handholes shall be located such that worker's accessing the handhole shall face oncoming traffic directly or located on the backside of the pole facing the roadway.
- e. Pole Cap. Top of the shaft shall be enclosed with a removable cap. The cap shall be secured in place with three each, 6 mm (1/4 in.) diameter, 300 series stainless steel screws coated with anti-sieze compound. The design of the cap shall be such that it shall not permit entry of water into the shaft.



- f. Grommets. Two 38 mm (1 1/2 in.) diameter openings at the top portion of the shaft, shall be made and two 31 mm (1 1/4 in.) inside diameter rubber grommets shall be provided, for wiring purposes through the top member(s) of the mast arm(s). Except where special mast arm orientations are shown, the grommet openings shall be at 90 degree angles from the position of the handhole, i.e., there shall be two grommet openings for each shaft, 180 degrees apart from each other and at 90 degrees apart from the handhole.

(3) Davit Style.

- a. General. The pole shall be designed such that deflection of the pole from the vertical axis does not exceed one degree per 3 m (10 ft) of nominal pole height as caused by the deadweight moment of the arm and design load luminaire referenced above.

Pole deflection calculations, certified by the manufacturer, shall be submitted to the Engineer as part of the data and product information submitted for approval. The calculations shall be for all lower shaft davit arm calculations applicable to the project.

The pole shall be coordinated with all luminaires being provided to be free of susceptibility to harmful harmonics and vibrations. The pole shall incorporate an integral vibration damper. The information submitted for approval shall address this requirement.

The combined assembly shall produce a luminaire mounting height as shown on the plans. Mounting height is defined as the distance from the tenon centerline to the bottom of the pole base.

Each pole shall be a two piece assembly consisting of a round lower pole shaft and a round upper short radius davit arm. The pole-arm assembly shall be part of a coordinated system with components designed such that a common lower shaft of each pole type will accept a variety of different length davit arms. Evidence shall be submitted that the pole will provide such a system, including not only the davit arm lengths specified or indicated for this project, but other arm lengths as well. As a minimum the system shall allow configurations with the following arms for each pole height:

- 2.4 m (8 ft) single
- 3.0 m (10 ft) single
- 3.6 m (12 ft) single
- 4.5 m (15 ft) single
- 2.4 m (8 ft) twin

Both the lower shaft and the upper davit arm shall be of smooth circular cross section seamless tapered aluminum alloy, Type 6063-T6. They shall be free of dents, kinks, ripples, scratches or

other defects. The outer wall shall have a satin ground finish, 100 grit or finer.

- b. Upper Arm. The upper arm shall slip fit over the lower shaft not less than 300 mm (12 in.) and the assembly shall be held in place with two stainless steel bolts with associated stainless steel nuts, flat washers and lockwashers. Each bolt shall be threaded only at its end so as to minimize the potential for damage to the pole wire (no threads on inside of pole). The flush joint shall be as shown on the contract plans.

Davit arms of various arm lengths, shall be suitable for the lower shaft, regardless of mounting height and the limitation of types.

The bend shall be carefully made so that the arm is free of kinks, wrinkles or other defects.

The upper end of the arm shall have a 60 mm (2 3/8 in.) outside diameter tenon with an extension of not less than 190 mm (7 1/2 in.) or more than 265 mm (10 1/2 in.). The tenon shall be coordinated with the luminaires being furnished for the contract so no more than 50 mm (2 in.) of the tenon between the upper end of the davit arm and the luminaire is exposed.

The davit arm shall be of the short radius type, having a centerline bending radius not greater than 1145 mm (45 in.). The bend shall produce a nominal up tilt of the arm not to exceed 5 degrees for an unloaded pole and 1.5 degrees for a loaded pole. The arm shall be coordinated with the luminaire furnished and produce a level mounting of the luminaire (up tilt not greater than 1.5 degrees) with the luminaire installed. Submittal information shall include conformation of this coordination.

The davit arm, regardless of mounting height, shall have a 150 mm (6 in.) outside diameter at the slip joint and shall taper to a 90 mm (3 1/2 in.) outside diameter at the luminaire end.

Each davit arm shall have a wall thickness of not less than 4.8 mm (0.188 in.).

- c. Lower Shaft. The shaft shall have a cast aluminum base plate, slotted holes for the base plate, base plate bolt circle, handhole, ground lug, and wall thickness as specified for the mast arm style pole in Article 1069.01(b)(2).

The lower shaft for 10.6 m (35 ft) mounting height poles or less shall have a 200 mm (8 in.) bottom diameter and shall taper to a consistent outside diameter of 150 mm (6 in.) at a point 7.95 m (26 ft. 1 in.) for 10.6 m (35 ft) mounting height pole or at a point 6.43 m (21 ft. 1 in.) for 9.1 m (30 ft) mounting height poles up from the base.

The lower shaft for light poles greater than 10.6 m (35 ft) but less than 15.2 m (50 ft) mounting height shall have a 250 mm (10 in.) outside bottom diameter and shall taper to a consistent outside diameter of 150 mm (6 in.) at a point 11.76 m (38 ft. 7 in.) up from the base.

(4) Tenon Top Style.

- a. General. The pole shall come complete with a twin tenon bracket (when required), and incidentals necessary to complete the installation. When a twin tenon bracket is required, it shall be a pole mount and not a tenon mount bracket.
- b. Tenon Top. The pole shall be designed and manufactured for twin 45 kg (100 lb) luminaires having an effective projected area each of 0.36 sq m (3.85 sq ft) on a twin tenon bracket. Poles shall meet the AASHTO loading criteria referenced above and pole deflection. Deflection of the pole top as caused by the combined effect of wind and the deadload of the twin luminaires referenced above shall be limited to one degree per 3 m (10 ft) of nominal pole height. Pole deflection and loading calculations, certified by the manufacturer, shall be submitted to the Engineer as part of the data and product information submitted for approval.

A tenon shall extend 150 mm (6 in.) above the pole top and meet AASHTO loading requirements for the luminaires referenced above. The tenon shall have an outside diameter of 75 mm (3 in.) and shall be made of the same material as the pole shaft.

The indicated mounting height for the tenon top pole shall be taken from the bottom of the pole base plate and shall be measured to the top of the pole.

- c. Shaft. The shaft shall have a cast aluminum base, slotted holes in the base plate, base plate bolt circle, handhole, and ground lug as specified for the mast arm style pole in Article 1069.01(b)(2). Poles with mounting heights of 10.6 m (35 ft) or less shall have a single piece shaft with a 200 mm (8 in.) outside bottom diameter tapering to a 115 mm (4.5 in.) outside top diameter. These poles shall have a minimum wall thickness of 4.8mm (0.188 in.) and shall be increased as necessary to satisfy the design loading requirements. Poles with mounting heights greater than 10.6 m (35 ft) shall have a shaft with a 250 mm (10 in.) outside bottom diameter tapering to a 150 mm (6 in.) outside top diameter. The minimum wall thickness shall be 5.6 mm (0.219 in.) and shall be increased as necessary to satisfy the design loading requirements.

One-piece poles shall be provided up through a 15.2 m (50 ft) mounting height. Two piece poles shall be designed with the upper section slip-fit over the lower section and the slip joint shall be designed to accommodate the pole's design loading requirements

but in no case shall the joint be less than 300 mm (12 in.). The joint shall be held together with two stainless steel 12 mm (0.50 in.) bolts and associated stainless steel flat washers, lock washers, and nuts. Only the portion of the bolts extending through the pole shall be threaded so as to eliminate threads inside the pole and minimize the potential for damage to the pole wiring.

(c) Steel Poles.

(1) General. One-piece poles shall be furnished.

Pole shafts for mounting heights of 10.6 m (35 ft) or less shall have a 200 mm (8 in.) outside bottom diameter tapering to a 100 mm (4 in.) outside top diameter and shall have a 290 mm (11 1/2 in.) bolt circle. The minimum wall thickness shall be 10 gauge and shall be increased as necessary to satisfy the design loading requirements.

Pole shafts for mounting heights greater than 10.6 m (35 ft) but less than 15.2 m (50 ft) shall have a 250 mm (10 in.) outside bottom diameter tapering to a 100 mm (4 in.) outside top diameter and shall have a 375 mm (15 in.) bolt circle. The minimum wall thickness shall be 7 gauge and shall be increased as necessary to satisfy the design loading requirements.

Pole shafts for mounting heights greater than 15.2 m (50 ft) shall have a 250 mm (10 in.) outside bottom diameter tapering to a 100 mm (4 in.) outside top diameter and shall have a 375 mm (15 in.) bolt circle. The minimum wall thickness shall be 5 gauge and shall be increased as necessary to satisfy the design loading requirements.

(2) Galvanized Steel Poles.

a. General. The poles and hardware components shall be galvanized according to AASHTO M 111. Steel selected shall have a silicone content suitable for galvanizing.

b. Mast-Arm Style.

1. General. The pole shall be designed and manufactured to withstand loadings of up to and including a 34 kg (75 lb) luminaire having an effective projected area of 0.15 sq m (1.6 sq ft) for steel, on a single 1.2 m to 4.5 m (4 to 15 ft) mast arm, and shall also withstand loadings of up to and including the same luminaire on each of two 1.2 m to 3.6 m (4 to 12 ft) arms (twin) oriented at any angle from 45 to 180 degrees apart, meeting the criteria of AASHTO as specified above.

2. Shaft. The steel shall be according to ASTM A 595 Grade A or B. The shaft shall be smooth circular, tubular, tapered design.

3. **Base Plate.** The bottom portion of the shaft shall be fitted with a base. The base shall be welded to the shaft and be free from cracks and pores. The base shall conform to AASHTO M 270M Grade 250 (M 270 Grade 36) and shall have a minimum yield strength of 250,000 kPa (36,000 psi). The base shall be welded to the shaft and be free from cracks and pores. The base shall be equipped with anchor rod covers. Anchor rod slots shall be provided in the base to accommodate the required bolt circle diameter. The size of the slots shall be 32 x 50 mm (1 1/4 x 2 in.) as detailed on the pole drawing.
4. **Anchor Rod Covers.** The anchor rod covers shall be galvanized steel or ASTM 300 series stainless steel.
5. **Ground Lug.** Each pole shall be supplied with a ground lug inside the handhole of the same material as the pole shaft or stainless steel. The ground lug shall be formed inside the shaft or tapped into the frame, but in either case it shall be located adjacent to and accessible from the handhole. The ground lug shall be a 13 mm (1/2 in.) 13 hole used for attaching a mechanical grounding connector.
6. **Handhole.** The pole shall have an oval shaped opening in the side of the shaft, unless the pole is to be mounted on a transformer base. The centerline of the handhole shall be 450 mm (18 in.) from the bottom of the shaft. The handhole shall be 100 x 200 mm (4 x 8 in.) in size with the 200 mm (8 in.) dimension being situated vertically and in the same plane as any one of the sides of the base. The handhole cover shall be the same material as the pole shaft and shall be fastened to the frame with 6 mm (1/4 in.) 20 size stainless steel hex-head screws and the holes for the screws shall be tapped to match the screws. The handholes shall be located so worker's accessing the handhole shall face oncoming traffic.
7. **Pole Cap.** Top of the shaft shall be enclosed with a removable cap. The cap shall be secured in place with three each, 1/4 in. diameter, 300 series stainless steel screws coated with anti-seize compound. The design of the cap shall be such that it shall not permit entry of water into the shaft.
8. **Grommets.** Two 38 mm (1 1/2 in.) diameter openings at the top portion of the shaft, shall be made and two 31 mm (1 1/4 in.) inside diameter rubber grommets shall be provided, for wiring purposes through the top member(s) of the mast arm(s). Except where special mast arm orientations are shown, the grommet openings shall be at 90 degree angles from the position of the handhole, i.e., there shall be two grommet openings for each shaft, 180 degrees apart from each other and at 90 degrees apart from the handhole.

## c. Davit Style

1. General. The davit arm shall be of the short radius type, having a centerline bending radius of 1140 mm (45 in.), 610 mm (24 in.) for twin davit arms. The bend shall produce a maximum up tilt of the arm of three degrees for an unloaded pole and 1.5 degrees for a loaded pole. The arm shall be coordinated with the luminaire furnished under the contract so as to produce a level mounting of the luminaire (up tilt not greater than 1.5 degrees) with the luminaire installed. Submittal information shall include conformation of this coordination.

Each pole shall be a two piece assembly consisting of a round lower pole shaft and a round upper short radius davit arm. The pole-arm assembly shall be part of a coordinated system with components designed such that a common lower shaft of each pole type will accept a variety of different length davit arms. Evidence shall be submitted that the pole will provide such a system, including not only the davit arm lengths specified or indicated for this project, but other arm lengths as well. As a minimum the system shall allow configurations with the following arms for each pole height:

2.4 m (8 ft) single  
 3.0 m (10 ft) single  
 3.6 m (12 ft) single  
 4.5 m (15 ft) single  
 2.4 m (8 ft) twin

The lower shaft and the upper davit arm shall be of smooth circular tapered cross section. The components shall be fabricated from high strength steel, with a minimum yield strength of 414,000 kPa (60,000 psi) and 689,000 kPa (100,000 psi) minimum tensile strength after fabrication. The longitudinal weld shall have a minimum 60 percent weld penetration. The components shall be free of dents, kinks, ripples, scratches, or other defects. The outer galvanized surfaces shall have a satin finish.

The combined assembly shall produce a luminaire mounting height as shown on the plans. Mounting height is defined as the distance from the tenon centerline to the bottom of the pole base.

2. Upper Arm. The davit arm shall slip fit over the pole shaft not less than 150 mm (6 in.) and the assembly shall be held in place with two stainless steel bolts with associated stainless steel nuts, flat washers and lockwashers. Each bolt shall be threaded only at its end so as to minimize the potential for damage to the pole wire (no threads on inside of pole). The flush joint shall be as shown on the contract plans.

The davit arm shall have a 90 mm (3 1/2 in.) minimum inside diameter at the slip joint and a 50 mm (2 in.) minimum outside diameter at the luminaire end. The upper end of the arm shall have a 50 mm (2 in.) outside diameter tenon with an extension of not less than 190 mm (7 1/2 in.) or more than 265 mm (10 1/2 in.). The tenon shall be coordinated with the luminaires being furnished for the contract so no more than 50 mm (2 in.) of the tenon between the upper end of the davit arm and the luminaire is exposed.

Davit arms of various arm lengths, shall be suitable for the lower shaft, regardless of mounting height and the limitation of types. The bend shall be carefully made so that the arm is free of kinks, wrinkles or other defects.

Each davit arm shall have a wall thickness of not less than 3.8 mm (149 mils).

3. Lower Shaft. The shaft shall be fabricated from high strength steel, with a minimum yield strength of 414,000 kPa (60,000 psi) and 689,000 kPa (100,000 psi) minimum tensile strength after fabrication. The longitudinal weld shall have a minimum 60 percent weld penetration.

The lower shaft for 10.6 m (35 ft) mounting height poles or less shall have a 200 mm (8 in.) bottom diameter and shall taper to a consistent outside diameter of 100 mm (4 in.) at a point 7.95 m (26 ft 1 in.) for 10.6 m (35 ft) mounting height pole or at a point 6.43 m (21 ft 1 in.) for 9.1 m (30 ft) mounting height poles up from the base.

The lower shaft for light poles greater than 10.6 m (35 ft) but less than 15.2 m (50 ft) mounting height shall have a 250 mm (10 in.) outside bottom diameter and shall taper to a consistent outside diameter of 100 mm (4 in.) at a point 11.76 m (38 ft 7 in.) up from the base.

The lower shaft shall have a base plate, slotted holes for the base plate, handhole, and ground lug, as specified for the mast arm style pole in Article 1069.01(c)(2)b.

d. Tenon Top Style.

1. General. The pole shall come complete with a twin tenon bracket (when required), and incidentals necessary to complete the installation. When a twin tenon bracket is required, it shall be a pole mount bracket unless calculations are submitted to verify the adequacy of a tenon mount bracket.

2. Tenon Top. The pole shall be designed and manufactured for twin 45 kg (100 lb) luminaires having an effective projected area each of 0.36 sq m (3.85 sq ft) on a twin tenon bracket. Poles shall meet the AASHTO loading criteria referenced above. Pole loading calculations, certified by the manufacturer, shall be submitted to the Engineer as part of the data and product information submitted for approval.

A tenon shall extend 150 mm (6 in.) above the pole top and meet AASHTO loading requirements for the luminaires referenced above. The tenon shall have an outside diameter of 75 mm (3 in.) and shall be made of the same material as the pole shaft.

The indicated mounting height for the tenon top pole shall be taken from the bottom of the pole base plate and shall be measured to the top of the pole.

3. Shaft. The pole shaft as well as the pole base, handhole, and ground lug shall be as specified for the mast arm style pole in Article 1069.01(c)(2)b.

### (3) Stainless Steel Poles.

- a. Mast Arm Style. The mast arm shall be made according to ASTM A 201L.

The mast arms shall be supplied with fabricated stainless steel brackets welded to the arms. The fastening of the arms to the shaft shall be clamp type bracket with stainless steel bolts, nuts and lockwashers.

All hardware shall be according to ASTM 300 series.

The mast arm, when required, shall be set at right angles to the centerline of the pavement. The leveling area of the luminaire shall be set in a plane parallel to the roadway taking into consideration the up or down grade and the superelevation of the roadway.

- b. Davit Style.

1. General. The davit arm shall be of the short radius type, having a centerline bending radius of 1140 mm (45 in.), 610 mm (24 in.) for twin davit arms. The bend shall produce a maximum up tilt of the arm of three degrees for an unloaded pole and 1.5 degrees for a loaded pole. The arm shall be coordinated with the luminaire furnished under the contract so as to produce a level mounting of the luminaire (up tilt not greater than 1.5 degrees) with the luminaire installed. Submittal information shall include conformation of this coordination.



Each pole shall be a three piece assembly consisting of a rectangular pole base, polysided lower pole shaft and a round upper short radius davit arm. The pole-arm assembly shall be part of a coordinated system with components designed such that a common pole base, lower shaft assembly of each pole type will accept a variety of different-length davit arms. Evidence shall be submitted that the pole will provide such a system, including not only the davit arm lengths specified or indicated for this project, but other arm lengths as well. As a minimum the system shall allow configurations with the following arms for each pole height:

- 2.4 m - (8 ft.) single arm
- 3.0 m - (10 ft.) single arm
- 3.6 m - (12 ft.) single arm
- 2.4 m - (8 ft.) twin arm

For narrow median mounting, the base plate, lower shaft and the upper davit arm shall be of smooth circular cross-section. The components shall be fabricated from high strength Type 201 stainless steel, with a minimum yield strength of 414,000 kPa (60,000 psi) and 689,000 kPa (100,000 psi) minimum tensile strength after fabrication. The longitudinal weld shall have a minimum 60 percent weld penetration. The components shall be free of dents, kinks, ripples, scratches, or other defects. The outer surfaces shall have a satin finish.

2. Upper Arm. The davit arm shall slip fit over the pole shaft not less than 150 mm (6 in.) and the assembly shall be held in place with two stainless steel set screws.

The davit arm shall have a 90 mm (3 1/2 in.) inside diameter at the slip point and a 50 mm (2 in.) outside diameter at the luminaire end.

Each davit arm shall have a minimum wall thickness of 2.8 mm (0.109 mils).

3. Lower Shaft. The base and base plate shall be fabricated from Type 201 stainless steel.

The base shall be a tapered design with a rectangular base plate with a maximum 225 mm (9 in.) width to accommodate six anchor rods. The base shall securely slip fit into the lower shaft with a 375 mm (15 in.) overlap. The tapered base shall conceal the anchor rods.

The base shall include a 175 x 280 x 355 mm (7 x 11 x 14 in.) flush mounted reinforced access door secured with stainless steel hardware.

The base shall be equipped with a 13 mm (1/2 in.) tapped hole for connection of the mechanical grounding connector.

The shaft shall be fabricated from high strength Type 201 stainless steel, with a minimum yield strength of 414,000 kPa (60,000 psi) and 689,000 kPa (100,000 psi) minimum tensile strength after fabrication. The longitudinal weld shall have a minimum 60 percent weld penetration. Minimum wall thickness shall be 2.8 mm (109 mils).

(4) Weathering Steel Pole.

The pole shall consist of a tapered shaft, anchor rods, nuts, bolts, washers, and incidentals necessary to complete the assembly and shall include a base plate, pole cap, handhole and cover. Each pole shall bear a name plate or other type of indelible marking or brand that shall identify it as to type, catalog number, and manufacturer.

The pole shall be designed and manufactured to withstand a luminaire effective projected area (EPA) of 0.36 sq m (3.85 sq ft) and maximum weight of 45 kg (100 lb) each for two tenon mounted luminaires on a twin tenon bracket.

The pole shall be fabricated from high strength, low alloy steel according to ASTM A 595, Grade C, or A 606, Type IV, minimum yield 345,000 kPa and 483,000 kPa (50,000 psi and 70,000 psi) respectively. The base shall be fabricated, cast, or forged according to AASHTO M 270M Grade 345 W (M 270 Grade 50 W). The handhole rim shall be fabricated of ASTM A 714, standard black pipe welded in a hole cut in the pole shaft. Handhole cover shall be made from 12 gauge minimum, weathering steel. The handhole shall have a clear opening not less than 117 x 178 mm (4.63 x 7 in.). Brackets for twin units shall be fabricated from 50 mm (2 in.) schedule 40 pipe 208,000 kPa (30,000 psi) minimum yield strength, painted with a prime coat of corrosion inhibiting polyamide epoxy and a finish coat of aliphatic acrylic polyurethane of a color to match aged weathering steel.

All shafts shall have a circular or multi-sided cross section. The centerline alignment shall not vary from base to pole top by more than 6 mm/3 m (1/4 in./10 ft) of pole height, but not to exceed 0.1 percent of the pole height.

The pole's outside surface and base plate shall be blasted according to Steel Structures Painting Council - SP6 (commercial blast) and cleaned at the factory to remove all surface contamination. The surface area shall be free of any oil and other foreign elements. All weld spatter shall be removed, and the surface shall be an even texture, free from marks, burrs, sharp edges, or imperfections.

Each pole shall be supplied with a stainless steel lug on the shaft for grounding purposes. The anchor rod nut covers may be made of steel, malleable iron or ferrous alloy. The handhole cover and nut covers shall be secured with hexagonal head stainless steel screws.

Anchor rods shall be the size indicated on the plans. Anchor rods shall be furnished with nuts and washers to provide for an adequate bearing surface. The pole shall be fastened with a nut, lock, and flat washers, poles shall be provided with breakaway support couplings of the type indicated in Article 1070.04.

Tenon top poles supplied for multi-mount luminaires shall be furnished with a 75 mm (3 in.) O.D. X 150 mm (6 in.) long tenon.

(d) Wood Pole.

Wood poles shall be preservative-treated according to the American Wood Preservation Standard C4 and designated per Standard M6. Wood poles shall meet the requirements of ANSI 05.1. Poles shall be marked and have other documentation to confirm compliance with this requirement as well as the class designation.

Poles shall also meet the following requirement in addition to ANSI 05.1: Poles will not be acceptable if they contain indentations attributed to loading or handling slings that are 6 mm (1/4 in.) or more deep over 20 percent or more of the pole circumference, or more than 13 mm (1/2 in.) deep at any point. Other indentations or abrasions, for example, forklift damage, chain saw damage etc., shall not be more than 1/10 the pole diameter at the point of damage up to a maximum 25 mm (1 in.). Such damage will be permitted in an oversized section, where the excess of wood will be taken into consideration in evaluating the effects of the damage. In any case, the circumference for a given class will still be required to be not less than the specification minimum.

(e) Fiberglass Pole.

(1) General. The pole shaft shall contain a minimum of 65 percent glass fibers by weight. The glass fibers shall consist of a commercial grade of "E" glass or better.

a. Finish. All fiberglass poles shall have a smooth consistent finish, free from marks and imperfections. Glass fibers shall be covered with a surfacing veil consisting of a saturated polyester cloth of 0.38 mm (15 mil) minimum thickness.

An outer layer of 0.25 mm (10 mil) minimum thickness of polyester resin with UV inhibitor shall be covered with a final coating of polyurethane to a minimum thickness of 0.04 mm (1.5 mil). All thickness minimums shall be a dry coating thickness.

- b. **Bond Strength.** The structural fibers and surfacing veil shall be constructed in a continuous process using a homogeneous resin mix to insure a strong molecular bonding of all adjoining layers.
  - c. **Guarantee.** The pole shall have a minimum ten year written warranty against delamination, fiber exposure, crazing, chalking, and shall cover all aspects of the finished pole against defect including fittings and hardware.
- (2) **Assigned Loading.** The detailed design and fabrication of the pole, including shaft, base, coupling, and arms (as applicable) shall meet AASHTO loading criteria according to the "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals" current at the time the project is advertised. The pole shall be designed such that deflection of the pole tip from the vertical axis does not exceed one degree/3 m (10 ft) of nominal pole height as caused by wind loading in combination with the deadweight moment of the luminaire(s), bracket and arm(s) as applicable. Pole deflection and loading calculations, certified by the manufacturer, shall be submitted to the Engineer as part of the data and product information submitted for approval. Special notation shall be made to show that localized pole buckling has been considered and properly accounted for in the calculations.
- (3) **Luminaire Load.** A tenon top pole shall be designed and manufactured to withstand the loading of up to and including two (twin) 45 kg (100 lb) luminaires having an effective projected area each of 0.36 sq m (3.85 sq ft) on a twin tenon bracket. Poles with arms shall be designed and manufactured to withstand loadings of up to and including a 34 kg (75 lb) luminaire having an effective projected area of 0.15 sq m (1.6 sq ft) on a single 4.5 m (15 ft) arm, and withstand loadings of up to and including the same luminaire on each of two 3.6 m (12 ft) arms (twin) oriented at 180 degrees apart. A mast arm pole shall also withstand loadings of twin arms at any angle from 45 to 180 degrees apart. These loading requirements shall also include all luminaire and mast arm combinations possible for the given pole height, up to and including the limits given. Information submitted for approval shall document satisfaction of these requirements.
- (4) **Shaft.** The shaft shall be spun to a smooth circular, tubular, seamless, tapered design and shall be free of dents, kinks, ripples, voids, scratches or other defects. Poles shall have a single piece shaft with a 250 mm (10 in.) minimum outside bottom diameter tapering to a 130 mm (5 in.) minimum outside top diameter. Poles may have an embedded stub section, as approved by the Engineer, for direct embedded poles.
- a. **Anchor Base.** The bottom portion of the shaft shall be fitted with an anchor base. The base shall be galvanized steel or a permanent mold casting of aluminum alloy conforming to Aluminum Association designations 356.0 or A356.0, with final temper T6.

The base shall be permanently fixed to the shaft and sealed to prevent moisture ingress. The base shall be polyurethane coated to match the pole color and equipped with anchor rod covers. Poles with base plates shall have a 375 mm (15 in.) rod circle. Anchor rod slots shall be provided in the base to accommodate the required rod circle diameter. The size of the slots shall be 30 x 50 mm (1 1/4 x 2 in.) to accommodate 25 mm (1 in.) anchor rods.

- b. Direct Embed. The minimum embedment depth for direct embedded poles shall be 2 m (6 ft). A wireway opening shall be located 305 mm (12 in.) below groundline. The opening shall be 65 X 305 mm (2 1/2 in. X 12 in.) in size and oriented to be parallel to the roadway unless otherwise directed by the Engineer. The embedded portion of the pole shall be designed to insure rotational stability under load and test data shall be submitted to document this capability.
  - c. Breakaway Direct Embed. In addition to the pole embedment requirements stated above, breakaway poles shall be manufactured according to and shall have a listing of approval by the FHWA to the current AASHTO breakaway requirements as stated in the "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals."
- (5) Ground Lug. Each pole shall be supplied with a stainless steel ground lug inside the handhole of the pole shaft.. The ground lug shall be a 13 mm (1/2 in.) mechanical grounding connector.
- (6) Handhole. The pole shall have an oval shaped opening in the side of the shaft, unless the pole is to be mounted on a transformer base. The centerline of the handhole shall be 450 mm (18 in.) from the bottom of the shaft or groundline mark. The handhole shall be 100 x 200 mm (4 x 8 in.) in size with the 200 mm (8 in.) dimension being situated vertically and in the same plane as any one of the sides of the base. The opening in the shaft shall be reinforced with a handhole frame situated on the inside of the shaft and bonded to the shaft or other means approved by the Engineer. The handhole cover shall be fastened to the frame with 6 mm (1/4 in.) 20 size stainless steel hex-head screws and the holes for the screws shall be tapped to match the screws. The handholes shall be located so worker's accessing the handhole shall face oncoming traffic.
- (7) Mast Arm Style.
- a. General. The indicated mounting height shall be taken from the bottom of the pole shaft base plate and shall be obtained with a nominal mast arm rise of 1,144 mm (45 in.) as specified.
  - b. Mast Arm. Top members of the arms shall have raceway openings extending through the bracket. Raceway openings shall be free of burrs and rough edges that may be injurious to the wires.

Exterior surfaces of the mast arms shall be free of all protuberances, dents, cracks, or other imperfections. The rise of the mast arm, shall be a nominal 1,144 mm (45 in.). The mast arm shall be made of aluminum alloy tube, round, seamless, according to ASTM B 221 and 6063 T6.

The mast arms shall be supplied with fabricated aluminum brackets welded to the arms. All welds shall be heat treated after welding. The fastening of the arms to the shaft shall be clamp type bracket with stainless steel bolts, nuts, and lockwashers.

- c. Grommets. Two rubber grommets, sized to the diameter of the mounting plate hole, shall be provided, for wiring purposes through the top member(s) of the mast arm(s). Except where special mast arm orientations are shown, the grommet openings shall be 90 degree from the handhole.

- (8) Tenon Top Style. A tenon shall extend 150 mm (6 in.) above the pole top. The tenon shall be coordinated with the luminaires being furnished for the contract so none of the tenon between the pole top and the luminaire is exposed. The tenon shall be schedule 80 galvanized steel pipe or ASTM 6061-T6 aluminum with an outside diameter of 75 mm (3 in.) permanently bonded to the shaft. The indicated mounting height for the tenon top pole shall be taken from the bottom of the pole base plate or groundline mark and shall be measured to the top of the pole.
- (9) Pole Cap. Top of the shaft shall be enclosed with a removable cap. The cap shall be secured in place with three 6 mm (1/4 in.) diameter, 300 series stainless steel screws. The design of the cap shall be such that it shall not permit entry of water into the shaft.
- (10) Pole Identification. Each pole shall have a permanently stamped metal plate that shall identify it as to manufacturer, lot number, and date of manufacture which shall be located on the top of the base plate or other location approved by the Engineer.
- (11) Base Protection. The pole shall have a groundline collar which shall protect the pole from abrasion by mowers and other equipment. It shall provide complete protection for the pole at groundline and extend up to the handhole without interfering with handhole access. The collar shall be securely fastened, rugged, removable, and UV resistant.

#### **1069.02 Pole/Unit Identification.**

- (a) Roadway Lighting Unit. Each pole, light tower and underpass light shall be labeled as indicated in the plans to correspond to actual circuiting, and as designated by the Engineer. They shall be installed by the Contractor on each lighting unit pole shaft and on the underpass walls, or piers, as shown in the details. Median-mounted poles shall have two sets of identification labeling oriented to allow visibility from travel in either direction. Lighting

controllers shall also be identified by means of identification decals as described herein. Identification shall be in place prior to placing the equipment in service. Identification of weathering steel poles shall be made by application of letters and numerals as specified herein to an appropriately sized 3.175 mm (1/8 in.) thick stainless steel plate which shall be banded to the pole with two stainless steel bands. Identification of painted poles shall be made by application of letters and numerals as specified herein via an adhesive approved by the paint manufacturer for the application. Identification of luminaires which are not pole mounted, such as underpass luminaires, shall be done using identification brackets. In general, the brackets shall be mounted adjacent to and within 300 mm (1 ft) of their respective luminaires. The brackets shall be fabricated from 3 mm (1/8 in.) in. aluminum alloy sheet according to the dimensions shown on the plans. The bracket shall be bent so as to present the luminaire identification numbers at a 60 degree angle to the wall. The bracket shall be attached to concrete walls with three 6 mm (1/4 in.), self drilling, snap-off type galvanized steel concrete anchors set flush with the wall, or power driven fasteners approved by the Engineer. The brackets shall be offset from the wall with 13 mm (1/2 in.) aluminum bushings. The structural steel shall not be drilled to attach the brackets. The luminaire identification numbers shall be applied to the bracket using the method described for identification applied to poles.

- (1) The letters and numerals for 18 m (60 ft) and less mounting height lighting units and underpass lighting units shall be 100 mm (4 in.) high, black, series "D" as described in the Federal Highway Administration's "Standard Alphabets for Highway Signs". Placement of numbers shall be as shown on the plans. The placement of the numbers shall be coordinated with the accident reference marker and handhole door as applicable. The letters and numerals shall be screened on silver-white, pressure sensitive, reflective, 114 mm (4 1/2 in.) by 100 mm (4 in.), Type A sheeting according to applicable portions of Section 1091. An alternate color scheme, such as black on yellow, shall be used as directed by the Engineer or indicated in the plans when the lighting system is not maintained by the Illinois Department of Transportation.
- (2) The letters and numerals for poles of a mounting height equal to and greater than 21 m (70 ft) shall be 225 mm (9 in.) high by 200 mm (8 in.) wide. The material of the decals and placement of numbers shall be as shown on the plans.
- (3) The letters and numerals for illuminated signs shall be 225 mm (9 in.) high x 200 mm (8 in.) wide. The material of the decals and placement of numbers shall be as shown on the plans.
- (4) Circuit identification for wood poles shall be made by the use of weather-resistant reflective letter tags in vertical slide in holders. Letter tags shall be reflective, black on yellow, with characters 75 mm (3 in.) high on tags nominally 65 x 90 mm (2 1/2 x 3 5/8 in.) in size. Slide in holders shall be aluminum and shall have both ends crimped after tags

are inserted. The holders shall be attached to the poles with 38 mm (1 1/2 in.) aluminum nails as recommended by the tag manufacturer.

**1069.03 Mounting Pad.** When mounted on bridges, a 13 mm (1/2 in.) thick vibration isolation mounting pad shall be included with the pole. The pad shall have the same shape as the bottom of the pole base with appropriate bolt holes and opening for the center of the pole. Included with the pad shall be four 10 mm (3/8 in.) thick washers. The pad and washers shall be made from a rugged elastomeric material. The ultimate breakdown of the pad and washers under compressive load shall be not less than 69,000 kPa (10,000 psi) for the specified thickness without extrusion or detrimental reduction in thickness. The material shall also have a Shore-A Durometer reading of not less than 80.

**1069.04 Light Tower.**

- (a) General. Light towers (high mast poles) shall consist of any poles 24 m (80 ft) or more in length.

Each light tower shall be complete with internal, integral motorized lowering mechanism, luminaire ring, pole top hood, internal electric power cables, lightning rod, luminaire counter-weight (when applicable), and all appurtenances required for a complete operating unit.

The design shall be based upon AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals" current at the time the project is advertised and a total combined luminaire weight of 272 kg (600 lb) and having a total projected area of 7.3 sq m (24 sq ft). Also to be considered is AASHTO fatigue Category I.

Light towers shall be designed and constructed so no structural member or other component is applied in excess of the manufacturer's recommended rating (when applicable) or the published rating, whichever is lower.

The design of the tower shaft shall achieve a maximum, fully loaded deflection at the top of the pole, which is not greater than the following percentage of the tower height:

Light Tower Maximum Deflection			
Tower Height	Max Deflection	Tower Height	Max. Deflection
in meters	% of Height	in meters	% of Height
49	13.70	33	7.80
46	10.04	30	5.30
43	7.80	27	4.50
40	6.02	24	3.50
36	10.75		



Tower Height	Max Deflection	Tower Height	Max. Deflection
in feet	% of Height	in feet	% of Height
160	13.70	110	7.80
150	10.04	100	5.30
140	7.80	90	4.50
130	6.02	80	3.50
120	10.75		

The light towers shall be of a height and luminaire capacity as indicated and be of the nonlatching ring support design.

The tower manufacturer or lowering device manufacturer, shall warrant the entire coordinated assembly and shall be the manufacturer of either the tower shaft or the lowering mechanism.

- (b) Shaft. The tower shaft shall be a low deflection tapered shaft having polysided, circular, or elliptical cross sections. The shaft cross section at the top shall be not less than 190 mm (7.5 in.) in diameter. The shaft cross section at the bottom shall not be greater than that which is compatible with the base plate bolt circle specified, and shall not be less than 600 mm (24 in.) in diameter for new installations.

All tower shaft components, including, but not limited to the shaft sections, tower sections, base plates, handhole door, handhole reinforcing, rain gutter, and base plate, shall be fabricated from high strength, low alloy, steel with a minimum yield strength of 345,000 kPa (50,000 psi) according to AASHTO M 270M Grade 345 (M 270 Grade 50) or AASHTO M 270M Grade 345W (M 270 Grade 50W); ASTM A 595, Grade A or B; ASTM 607, Grade 50; ASTM A 606, Grade 50; ASTM A 715, Grade 50; ASTM A 808M (A 808).

Galvanized steel poles and base plates shall be fabricated from steel according to AASHTO M 270M Grade 345 (M 270 Grade 50), ASTM A 595, ASTM 607 or ASTM A 606, with a minimum yield of 345,000 kPa (50 ksi). After fabrication the pole shall be thoroughly cleaned and galvanized according to AASHTO M 111.

Each tower shaft shall be constructed of not more than the following welded or slip fitted sections:

Tower Height in meters	Maximum Number of Sections
40,43,46,49	4
27,30,33,36	3
24	2

Tower Height in feet	Maximum Number of Sections
130,140,150,160	4
90,100,110,120	3
80	2

Sections which are slip fitted shall have slip joints with a minimum overlap of 1.5 times the diameter of the bottom of the upper section at the slip joint. Towers having slip joint construction shall be prefitted and match marked at the factory and shall be shipped disassembled for assembly at the jobsite. Slip joints shall be marked to assure the 1.5 times diameter insertion is provided.

Each tower shaft shall be constructed with a handhole/access door for access to power connections and lowering mechanism equipment. The handhole shall be large enough to make the entire lowering mechanism assembly visible from an extended operating position and accessible for maintenance. The handhole shall be sized and arranged to permit removal of the lowering mechanism without excessive dismantling of the equipment. The handhole may be a reinforced opening in the pole shaft as detailed on the plans or may be a part of a flared shaft base assembly as approved by the Engineer. The flared base shall not be considered a separate section of the tower shaft. Minimum opening dimension for the handhole shall be 300 mm x 900 mm (12 in. x 36 in.) and lockable.

The handholes in the pole shafts shall have rounded corners and shall be reinforced to maintain the original strength of the tower shaft. Flared base assemblies shall maintain the strength of the shaft and have no nonround protrusions.

The handhole shall have a door with a full-height stainless steel piano hinge, or with not less than two stainless steel hinges, or with other hinge arrangement acceptable to the Engineer. A bolt through a door and frame eyelet shall not constitute an acceptable hinge. Hinges shall be heavy duty, suitable for the weight of the handhole door. The door/opening shall be gasketed in a manner which will prevent the entry of water into the pole and the door shall have a tight compressive seal employing a tubular gasket to assure compressibility. The door shall be held closed with a 12 gauge captive adjustable, spring loaded, stainless steel clamp assembly. The clamp assembly shall be held closed with deep slot stainless steel screws. The clamps shall have a depth stop feature to insure uniform sealing pressure at all clamp points. A minimum of three clamps shall be used around the nonhinged sides of the door assembly. A stainless steel padlock hasp and staple shall be provided for locking the door. Door hardware shall be stainless steel. The door shall be equipped with an integral door stop mechanism.

A rain shield shall be placed above the handhole to direct water away from the handhole. The shield shall be fabricated of the same material as the pole shaft, shall have rounded corners, and shall be permanently welded to

the shaft. Details of the configuration and welding shall be submitted for the Engineer's approval.

Each tower shaft shall have a handhole accessible ground lug welded to the shaft for connection of ground conductors. The lug shall be stainless steel and accessible with the lowering device installed.

The top of the shaft shall have a stainless steel ground lug welded to the tower shaft suitable for a bolted ground connection for a lightning rod.

A copper bonding jumper shall bond slip fit pole sections together with a flat copper mesh and stainless steel ground lugs.

The base plate shall be factory predrilled (slotted) for the number and configuration of anchor rods as provided in the following table:

Baseplate Configuration

Tower Height in meters	Minimum Number of Anchor Rods	Rod Circle (mm)
40,43,46,49	8	711-914
27,30,33,36	8	711-760
24	6	711-760

Tower Height in feet	Minimum Number of Anchor Rods	Rod Circle (in.)
130,140,150,160	8	28-36
90,100,110,120	8	28-30
80	6	28-30

The base plate shall have a round (disk) shape of the specified outer diameter or as otherwise approved by the Engineer. The minimum thickness of the base plate shall be 50 mm (2.0 in.).

The base plate shall be circumferentially welded to the tower shaft.

All tower shaft hardware, such as ground lugs, hardware for the handhole door, including the handle/latch mechanism, hinge and door stop, shall be stainless steel. Ground lugs shall be protected by removable plastic plugs or caps.

(c) Welding.

- (1) Requirements. Circumferential welds, including top flange welds, shall be full penetration welds.

Longitudinal welds shall have a minimum of 60 percent penetration, except the longitudinal welds on both the male and female shaft sections shall be full penetration welds within a distance of two diameters of overlap joints.

Minimum preheats for welds shall be 40 °C (100 °F) for fillets, 65 °C (150 °F) for seams, and 110 °C (225 °F) for circumferential welds.

Weld procedure specifications for seams and circumferential welds must be qualified according to Section 4, Part B of AWS D1.1. Charpy V-Notch (CVN) impact specimens shall be tested according to Table III-1 (note 2) of Appendix III for minimum values of 34 J (25 ft lb) at 4 °C (40 °F). Fillet weld procedures shall be tested according to Table 4.4 of AWS D1.1.

The welds shall be smooth and thoroughly cleaned of flux and spatter and be according to the AWS.

All full penetration welds shall be inspected for soundness by the ultrasonic method and all partial penetration welds shall be inspected by the magnetic particle method. Welding inspection reports shall be submitted to the Engineer for approval. The welding symbols and complete information regarding location, type, size, welding sequence, and WPSs shall be shown on all shop drawings. The Contractor shall submit the manufacturer's welding procedures to the Engineer for approval.

- (2) Inspection. In addition to manufacturer's own welding inspection, the Contractor shall have welding inspected by an independent Certified Welding Inspector (CWI). The selected inspector shall be approved by the Engineer before any inspecting is performed. The NDE inspector(s) shall be independent nondestructive testing inspector(s), certified as level II in RT, UT, and/or MT as applicable.

The methods for testing full penetration and partial penetration welds by the independent welding inspector(s) shall be the same as specified above.

The independent welding inspector shall send the test results directly to the Engineers, as follows: Illinois Department of Transportation, Attn: Engineer of Structural Services, 2300 S. Dirksen Parkway, Bureau of Bridges & Structures, Springfield, Illinois 62764 and to the applicable District Engineer.

(d) Light Tower Finish.

- (1) Painted Tower. Painted towers shall be completely painted inside and out, including the handhole, handhole door, base plate, mounting plate and all other elements welded to the shaft. The paint system shall consist of a prime coat and finish coat. The finish coat shall be applied to the outside surfaces only.

The prime coat shall be according to Section 506 and the finish coat shall be according to Article 1008.24 and Section 506. Stainless steel and electrical or mechanical components shall not be painted. The

color of the finish coat shall be according to Federal Standard Color Number 595A (dark chocolate).

- (2) Weathering Steel Towers. Weathering steel towers shall have the bottom 3 m (10 ft) painted including the handhole, handhole door, base plate, mounting plate and all other elements welded to the shaft. The paint shall be applied as specified above for a painted tower and the bottom of the tower shall be painted inside and out. In addition to the bottom 3 m (10 ft) of the tower, the male and female section of the slip joint(s) and the top surface of the head frame plate shall also be painted with prime and finish coat.

Surfaces of the weathering steel tower which are not to be painted shall be properly cleaned and prepared in order to form a uniform patina. These surfaces shall be free of any paint, weld splatter, oil, grease, or other foreign matter. Preparation shall be according to the Steel Structures Painting Council, (SSPC-SP-10) near white blast cleaning specifications to a surface profile of 25 to 75  $\mu\text{m}$  (1-3 mils).

- (3) Galvanized Steel Towers. Galvanized steel towers shall be galvanized including the handhole, handhole door, base plate, mounting plate and all other elements welded to the shaft according to AASHTO M 111.
- (e) Head Frame. Each tower shall be equipped with a head frame assembly to support and guide the luminaire ring assembly. The head frame and luminaire ring shall have a positive mating interface with the proper seating force applied to each guide pin when in the home position.

The guide pin housing for each support cable shall have a flared bottom section to help seat the cable guide pin. The cable guide pin shall be inserted a minimum of 100 mm (4 in.) into the guide pin housing. The cable shall be protected against wear in the head frame when in the fully seated (home) position.

The head frame plate and attached components shall be fabricated of the same type of steel as the tower shaft or of Type 201 stainless steel. It shall then be hot dipped galvanized according to AASHTO M 111 or painted as specified for the tower shaft or fabricated from stainless steel.

The head frame shall have a head plate, a pulley support and two pulleys for each support cable.

The head frame shall have a power cable pulley arrangement placed between and roughly equidistant from two support arms, and allow a minimum cable bending radius of not less than 163 mm (6 ½ in.). The head frame shall have a minimum diameter of 1 m (36 in.).

Pulley sheaves shall be constructed to allow associated cables to ride freely within pulley grooves and cable guides shall be incorporated to prevent cables from riding out of pulleys.

Attachment hardware, latches, hinges and the like shall be stainless steel. Pulleys shall be made of high quality steel and have permanently lubricated sealed bearings or when approved by the Engineer, bronze bushings.

The head frame assembly shall be equipped with a metal hood. The aluminum hood shall protect the operating head frame components from damage or deterioration from weather but shall permit pole ventilation while preventing the entry of birds.

The head frame assembly shall be match marked to its tower shaft and shall be attached to the shaft by stainless steel hardware.

- (f) Luminaire Ring. Each tower shall be provided with a luminaire ring suitable for the quantity, type, and orientation of the luminaires specified. The ring shall mate/align with the head frame and shall be coordinated relative to seating force.

The fully enclosed luminaire ring shall facilitate ease of wiring to the arms by removable gasketed doors. The open ring design shall incorporate a steel retainer strap welded to the ring at a 300 mm (1 ft) maximum spacing to keep the cord properly aligned with the ring. Both the enclosed and open ring design shall be free from protrusions or sharp edges that could damage the cord insulation.

The ring shall be equipped with bumpers, rollers, or other shock-absorbing mechanism to guide the ring during the raising/lowering operations. The guide mechanism shall be spring loaded or shall otherwise be designed to minimize shock to the luminaire during raising and lowering. Multi-mount luminaires shall have flexible, weatherproof conduit to transition the cord from the end of the tenon arm to the luminaire.

Arms for the attachment of luminaires shall be standard 50 mm (2 in.) diameter tenon arms. The arms shall be attached to the ring in a secure manner either by welding or by means of stainless steel bolts, nuts, lock washers and hardware such that a permanent rigid attachment is achieved. Arms shall be approximately 600 mm (24 in.) in length, coordinated with luminaire size and configuration and shall be arranged so that down lighting or multi-mount luminaires are accommodated as specified. The ring shall lower to 1.2 m (4 ft) above the bottom of the tower base plate or 1.5 m (5 ft) above the surrounding grade, whichever is lower.

The ring shall be equipped with an enclosed wire raceway and a stainless steel terminal box built according to NEMA 3R requirements for wiring of the luminaires. The box shall be equipped with a hinged door and latch or with captive stainless steel closure hardware acceptable to the Engineer and an external special fixed-mount plug with a retained cap according to Article 1069.04(p), to accept a test power connection when the ring is in the lowered position. The terminal box shall be of adequate size to house fuses and fuse blocks for a 10.3 mm x 38 mm (13/32 in. x 1 1/2 in.) "slow blow" cartridge fuse.

The box shall contain a terminal strip with identified terminals for connection of the main power cord, luminaires, and the test power receptacle. The ring shall facilitate ease of wiring to the arms by the use of removable gasketed covers. Arms shall be factory or field wired according to NEC Article 410-31 using No. 12 AWG, type "SO" cord, rated 105 °C, 12/2 w/ground.

Wiring shall be color coded (black, white and green, as applicable) with coloring via outer material color or by painting with a process approved by the Engineer. Wire rating information shall be visible in a contrasting color. Wires shall be installed to all luminaire arms. Luminaire wires shall extend 1.8 m (6 ft) longer than their respective tenon arm and shall be trained back into the arm which shall then be closed with a protective cap for shipment to the jobsite. All ring wiring shall be tagged with wire markers at both ends.

The luminaire ring shall be factory checked and marked for proper positioning and luminaire orientation. Catalog cuts and shop drawings shall indicate the orientation of the luminaire ring, handhole, and bolt circle in relation to each other on a single drawing.

The fully enclosed luminaire ring and attached components shall be fabricated of the same type of steel as the tower shaft or of Type 201 stainless steel. If it is not fabricated of stainless steel, it shall then be hot dip galvanized according to ASSHTO M 111 or painted according to Article 1069.04 (d) (1). An open ring system shall be fabricated of Type 201 stainless steel..

- (g) Lowering and Support Mechanism. The support shall be of the nonlatching design. The lowering and support scheme shall be of the two cable or three cable type as specified.

The lowering and support mechanism shall include, but not be limited to the support cables, hoist cable, internal drive unit and all accessories and appurtenances for a coordinated operating system.

Three cable mechanisms shall incorporate three support cables joined at a transition plate to a single hoist cable wound around a single hoist winch. The transition design shall utilize thrust bearings in order to prevent twisting of the hoist and support cables and to assure smooth winding of the cable on the winch.

Two cable mechanisms shall incorporate two support/hoist cables wound around a dual winch assembly. The design shall be such to prevent twisting of the cables and to assure smooth winding of the cables on their respective winch and to prevent binding on the inside of the tower shaft.

The hoisting system shall be securely mounted and the lower assembly, i.e. motor, winch, mechanical clutch, gear reducer, etc., shall be designed to allow ease in removal of the equipment via the tower handhole without dismantling the system. Individual components shall be accessible and removable without the removal of other components.

The device shall tightly position the luminaire mounting ring against the head frame assembly by applying a seating force of 1.3 kN (300 lb) minimum, to be distributed among the seating/interface points. There shall be a positive indication at the handhole or on the head frame that the required force has been applied, visible from the extended operating position away from the handhole and not under the ring.

The mechanism shall be equipped with a multipoint safety chain and hook assembly to hold the luminaire ring in place during maintenance. All hardware shall be stainless steel. Chains may be galvanized or stainless steel. Two chains are required for each tower.

The system shall be designed so that unbroken power cable, suspension and/or hoist cable can be replaced from ground level.

- (h) Support and Hoist Cables. Cables (wire rope) shall be manufactured from Type 304 or Type 316 stainless steel having a carbon content of 0.09 to 0.15 and shall be a stranded assembly coated with a friction-limiting non-corrosive lubricant.

Cables shall be 7x19 wire strand and have no strand joints or strand splices. Cables shall be manufactured and listed for compliance with military specification MIL-W-83420B, Type 1, Composition B.

Cable terminals shall be stainless steel compatible with the cable and as recommended by the cable manufacturer. The terminals, swaging, etc. shall meet the requirements of military specification MIL-T-781.

The support cables shall each be not less than 5 mm (3/16 in.) in diameter and the hoist cable shall not be less than 8 mm (5/16 in.) in diameter, for a three support cable system. For two cable systems, the support/hoist cables shall each be not less than 6 mm (1/4 in.) in diameter.

As part of the tower shop drawings and product data submitted for approval, support and hoist cable information shall be provided. The information shall include:

- (1) Catalog information to confirm sizing, stranding and other specified requirements.
- (2) Evidence of listing as military specification cable as specified.
- (3) Certification of compliance with all specification requirements made by the cable manufacturer.
- (4) Copies of recent test reports made on identical cable indicating compliance with military specification requirements. The test reports shall include as a minimum, the following:
  - a. Breaking Strength test.



- b. Endurance test.
  - c. Stretch test.
  - d. Test load.
  - e. Chemical Composition.
- (i) Winch. The winch shall have a drum suitable for the hoist of support/hoist cables, arranged to provide smooth winding of the cable and to prevent slippage. The drum shall be stainless steel or cast/ductile iron and shall have a diameter not less than 18 times the diameter of its respective cable (wire rope) and shall have tapered inside flanges. The winch drum shall be designed with cable guides for a smooth cable take-up of level lays and to prevent the cable from riding over the drum flange. The drum shall have the end of the cable attached by means of a swaged connection and one full layer of cable shall be wound on the drum when the ring is in the fully lowered position. The drum axle shall be supported at both ends.
- (j) Gear Reducer. Each assembly shall incorporate a gear reducer having a reduction ratio which will prevent free fall of the luminaire ring upon failure or disengagement of the drive unit and which will produce a travel rate of 3 m (10 ft) to 4.6 m (15 ft)/minute under normal operation.

The unit shall have a worm gear which is totally enclosed in a lubricating reservoir. The lubricant shall have a viscosity range suitable for proper operation in ambient temperatures from -40 °C to 49 °C (-40 °F to 120 °F). The worm shall be manufactured of case hardened ground alloy steel or cast iron. The unit shall have provisions to verify the oil level in the gear box.

The gear shall be of bronze alloy and keyed to the output shaft. The worm gear shaft and output shaft shall be mounted on antifriction bearings.

- (k) Clutch. The mechanism shall incorporate a mechanical clutch, installed between the winch/gear reducer and the motor. The clutch shall be of mechanical type, in a sealed cast metal housing. The clutch torque shall be factory calibrated and coordinated with the electric motor. The clutch shall act to limit the seating force of the raised ring to 1.3 KN (300 lb).
- (l) Motor. The electric motor shall be matched to the load and torque characteristics required for a loaded luminaire ring and shall not be less than 746 W (1 hp). The motor shall have built in over current protection and reset switch.

The motor shall be totally enclosed fan cooled (TEFC), shall be reversible to operate the lowering mechanism in both directions, and shall be of rated voltage compatible with power supplied to the tower.

Submittal information shall include complete motor data, including, but not limited to:

- (1) Manufacturer
  - (2) Nameplate Rated Watts (Horsepower)
  - (3) Rated Voltage
  - (4) Full Load RPM
  - (5) Full Load Current
  - (6) Locked Rotor Current
  - (7) NEMA Design Letter
  - (8) Insulation Class
  - (9) Torque Data
  - (10) Dimensional Data
  - (11) over Current Protection Data
  - (12) Calculations to verify the compatibility of the drive unit components (motor, gear reducer, clutch and winch).
- (m) Ring Lowering Controls. The control shall incorporate a reversing motor starter or reversing control switch. The motor starter shall be sized NEMA 1 as a minimum and shall be full voltage, rated 600 V, 2-pole reversing type with arc-extinguishing capabilities, and shall have a coil voltage as specified. The reversing control switch shall be a drum switch with a minimum rating of 2,240 W (3 hp).
- Either control device shall be capable of being operated remotely, at a distance of 7.5 m (25 ft) from the tower. The remote, "dead man" style switch shall be in a non-metallic, impact resistant, NEMA 4 enclosure. It shall have momentary contacts, up-stop-down settings, and require constant pressure by the operator to energize the circuit.
- (n) Power Supply. The power supply to the tower shall feed through a standard 2-pole fuseholder according to Article 1065.01 and connect to a surge arrester according to Article 1065.02 before terminating at the tower main breaker. The tower main breaker shall be housed in a stainless steel NEMA 4 enclosure with an external position-indicating operating handle having padlock provisions. The enclosure shall be mounted on the inside of the handhole access door and have two-color engraved nameplates clearly marking the "RESET", "ON", and "OFF" positions.

The main circuit breaker shall be a molded case, 2-pole, thermal magnetic, bolt-on type having a UL-listed interrupting rating of not less than 14,000 rms symmetrical amps at 480 V. The breaker shall be sized 30 A unless noted otherwise.

- (o) Flexible Cord. All cord in the tower handhole shall be No. 12 AWG with ground, portable power cable or hard service cord,. According to NEC Article 400. The cord shall be rated for extra hard-usage service 600 V, -60 °C to 105 °C (-76 °F to 221 °F), and shall be oil and water resistant. It shall extend through a watertight sealing bushing at all box and housing penetrations. All cords shall be reeled and neatly stored when housed in the tower handhole and arranged so as not to interfere with the lowering mechanism or closing of the handhole door.

The power cord running from the transition plate to the luminaire ring shall be Type W industrial grade portable power cord according to NEC, ICSA S-68-516, and WC-3, rated 90 °C (194 °F). The cord shall have a four-conductor, extra flexible jacketed construction with reinforced fillers to maintain a smooth round surface. Each conductor shall be No. 8 AWG stranded annealed copper.

- (p) Connectors. Connectors shall be "pin and sleeve" type to allow quick connections of the feed from the main breaker to the power cord at the transition plate, luminaire ring, and motor control circuit. Connectors shall be four pole, four wire, 600 V, 30 A, load-break, weatherproof devices. Each connection to the power cord shall include a non-metallic sealing connector body with a wire mesh strain relief. Both plug and receptacle shall be complete with retained flap-type or screw-on protective end cover.
- (q) Lightning Protection. A copper clad steel lightning rod 13 mm (1/2 in.) in diameter x 900 mm (36 in.) long shall be attached to the head of the frame and centered over the pole.

A flexible copper braid connector of #2 copper equivalent shall be installed between the lightning rod and grounding lug on the top of the tower shaft. Good metal-to-metal contact shall be assured by bolted connections using lugs and connectors specifically approved for the purpose.

Similar copper braid shall be attached with studs and exothermic welds at tower shaft sections or the shafts shall be electrically joined by other means approved by the Engineer.

A #4 solid bare soft drawn copper wire shall be attached between the grounding electrode at the foundation and a ground lug in the tower shaft at the handhole. The copper ground wire shall be exothermically welded to the grounding electrode.

## SECTION 1070. FOUNDATION AND BREAKAWAY DEVICES

**1070.01 Light Pole Foundation, Metal.** Metal foundations shall be fabricated from material new and unused in any previous application. The manufacturer shall provide a certification that the materials are new and meet the specified requirements and shall accompany the submittal.

Metal foundations shall be fabricated from steel.

Baseplate:	AASHTO M 270M, Grade 250 (M 270, Grade 36)
Shaft:	ASTM A 252, Grade 2 (Phosphorous 0.04% maximum)
Helix Screw:	ASTM A635
Pilot Point:	ASTM A575

Metal foundations shall be fabricated with two wiring entry slots parallel with the shaft axis and aligned with base plate faces 180 degrees apart. Each slot shall have rounded smooth edges, shall be 65 mm (2.5 in.) wide and 305 mm (12 in.) long and shall extend down from a point on the shaft 305 mm (12 in.) below the base plate. Continuous slots up and through the base plate will not be acceptable. When specified, the slot size shall be increased to approximately 75 mm (3 in.) wide and 686 mm (27 in.) long and shall extend down from a point on the shaft 225 mm (9 in.) below the base plate.

Foundation shaft diameters, baseplate size, shaft length and bolt circles shall be as detailed on the plans. Foundations shall be fully coordinated with specified poles.

Studs or threaded rods shall be furnished with the foundations. Studs or rods shall be 25 mm (1 in.) diameter and shall be according to AASHTO M 314. Nuts shall be hexagon nuts according to AASHTO M 291M (M 291) and washers shall be according to AASHTO M 293. Studs or rods, nuts and washers shall be hot dip galvanized according to AASHTO M 232. Metal foundations shall come complete with galvanized steel plates or plugs to fill any penetrations in the base plate which are in addition to the four threaded stud holes and the center wireway opening.

**1070.02 Anchor Rods.** Anchor rods shall be according to ASTM F1554 Grade 725 (Grade 105). Nuts shall be hexagon nuts according to ASTM A 194 2H or ASTM A 563 DH, and washers shall be according to ASTM F 436.

The entire length of the anchor rods as well as the nuts and washers shall be hot dip galvanized according to Article 1006.09. The anchor rods shall be threaded a minimum of 150 mm (6 in.) with a minimum of 75 mm (3 in.) of threaded anchor rod embedded in the foundation. The threaded anchor rod extension shall be coordinated with the light pole and breakaway device requirements, as applicable.

**1070.03 Light Tower Anchor Rod Assembly.** Anchor rods shall be straight and shall be according to AASHTO M 314 or ASTM F1554, Grade 725 (Grade 105) and galvanized according to Article 1006.09. Anchor rod information shall be submitted for approval and shall be fully coordinated with tower manufacturer's requirements. Reinforcement bars shall be according to Article 1006.10. Anchor rod nuts for all towers shall be the self-locking type with steel inserts..

**1070.04 Breakaway Devices.**

(a) Breakaway Couplings

- (1) General. Breakaway couplings shall be manufactured of cast aluminum or galvanized steel. Certification shall be submitted from the supplier

that the device used under the conditions of the particular design meets the AASHTO breakaway specification. Certification shall include test results performed by the manufacturer, supplier or others. If test results have been previously approved by a letter from the FHWA, a copy of the approval letter from FHWA should accompany the certification. The coupling shall not alter the bolt circle of the pole.

The breakaway device shall be vandal resistant and shall not adversely affect the light pole installation and maintenance or decrease the resistance of the light pole to non-collision type of design loading. The breakaway device shall be field attachable and detachable.

- (2) Breakaway Coupling Cover. The breakaway device shall have a cover enclosing the space between the bottom of the pole base plate and the foundation.

a. Aluminum Skirt. The cover shall be an aluminum skirt of a two piece design made of 3003 H14, or 5052 H32T aluminum alloy, 2 mm (0.080 in.) thick. The enclosure shall fit snugly around the breakaway devices between the bottom face of the pole base plate and top of the foundation. Vertical or horizontal movement of the enclosure will not be acceptable.

b. Fiberglass Shroud. When specified, the cover shall be a molded fiberglass shroud. The shroud shall be designed as a one piece fiberglass enclosure, capable of being installed over the base of the light pole and breakaway couplings, as shown on the plans. When installed on existing poles, the shroud may be a two piece assembly designed to be permanently joined in a manner which is tamper-resistant as approved by the Engineer. The shroud shall be dimensioned in a manner such that it will fit over light pole base designs with a bolt circle and shaft diameter as shown on the plans, and lateral movement shall be no greater than required to allow easy installation. The Contractor shall submit all dimensions necessary to confirm a proper fit. The shroud color shall be applied in a manner applicable to current industry practice for this type of material and use. The color shall be as approved by the Engineer. The Contractor shall submit samples of colors and materials for selection.

c. Stainless Steel Wire Cloth. The stainless steel wire cloth shall be installed to enclose the void between the pole base and the foundation.

(b) Transformer Base

- (1) The breakaway device shall be a cast and welded aluminum transformer base type pole base. The breakaway device shall have a listing of approval by FHWA to AASHTO breakaway requirements. This shall require compliance to "Standard Specifications of Structural

Supports for Highway Signs, Luminaires and Traffic Signals" published by AASHTO. Submittal information shall document the approval listing.

- (2) The device shall be approximately 430 mm (17 in.) high and shall have a large fiberglass or polyethylene access door of a color to match the base finish which shall be held in place with a button-type tamper resistant stainless steel screw or other means approved by the Engineer. The polyethylene access door shall be fabricated from a high density polyethylene. The door shall withstand temperature extremes of -60 °C to +65 °C (-76 °F to +150 °F). Ultraviolet light inhibitors shall also be incorporated into the door material. The door shall be gusseted and have tabs on the bottom to lock into the transformer base door frame.
- (3) The appearance of the breakaway device shall be of such general configuration as not to detract from the aesthetic value of the light pole. The device shall have a natural aluminum finish.
- (4) Bolt Circle Size. The transformer base shall come in two standard sizes.
  - a. 290 mm (11.5 in.) Pole Bolt Circle Devices. Breakaway devices for poles having nominal 290 mm (11.5 in.) bolt circles shall accommodate bottom (foundation) bolt circles ranging roughly 255 mm to 300 mm (10 to 12 in.) and shall accommodate top (pole) bolt circles ranging roughly 265 mm to 300 mm (10.5 to 12 in.).
  - b. 380 mm (15 in.) Pole Bolt Circle Devices. This device shall be furnished in one of two styles. The straight base device shall be furnished unless otherwise specified.
    1. Flared Base Device. The bottom foundation bolt circle shall have a range of 380 to 430 mm (15 to 17 in.) and shall accommodate top (pole) bolt circles having a range of 330 to 380 mm (13 to 15 in.).
    2. Straight Base Device. The bottom foundation bolt circle shall have a bolt circle of 380 mm (15 in.) and shall accommodate top (pole) bolt circles of 380 mm (15 in.).
- (c) Breakaway Shoe Base. Breakaway shoe or sleeve bases shall be made of cast aluminum with a 450mm (18 in.) sleeve insert. Pole diameters of 200mm (8 in.) at the bottom and 150 mm (6 in.) at the top shall have 290 mm (11.5 in.) bolt circles. Pole diameters of 255 mm (10 in.) at the bottom and 150 mm (6 in.) at the top shall have 380 mm (15 in.) bolt circles. Anchor rod nuts shall be torqued to the manufacturer's specifications.

TRAFFIC SIGNALS

SECTION 1071. TRAFFIC SIGNAL MISCELLANEOUS

**1071.01 Traffic Signal Paint.** The primer shall be a corrosion inhibiting, lead and chromate free, alkyd coating according to Federal Specification TT-P-645B or TT-P-664D.

The finish coats shall produce a hard mar-resistant coating, free from paint cracks, sags, blisters or other defects and be according to the following:

Yellow Enamel	Fed. Spec. TT-E-489H, color 13538
Dull (matte) Black	Fed. Spec. TT-E-527D, color 37038
Aluminum	Article 1008.20
(intermediate coat)	
Aluminum (final coat)	Article 1008.19

When a finished surface is struck a light blow with a sharp tool, the paint shall not crack or chip. When a finished surface is scratched with a knife, the paint shall not powder.

SECTION 1072. EMERGENCY VEHICLE PRIORITY SYSTEM

**1072.01 Emergency Vehicle Priority System.**

- (a) **System Requirements.** The system shall operate over an ambient temperature of -30 °C to 74 °C (-22 °F to 165 °F) and in 0 to 95 percent relative humidity.

All logic and timing circuitry shall be solid state. All printed circuit assemblies shall be according to NEMA Standards for Traffic Control Systems, TS 1.

- (b) **Light Transmitter.** The transmitter shall transmit a pulsed high intensity light energy in a forward direction. The on/off condition shall be controlled by an on/off switch and shall be indicated by a light located adjacent to the switch.

The transmitter shall operate on 10 to 15 VDC input voltage, but shall not be damaged by input voltage surges up to 25 VDC.

The transmitter shall not generate voltage transients on the battery input line which exceed the battery voltage by more than 4 V.

- (c) **Light Detector.** The detector shall be capable of receiving high intensity light energy from one or both of two axially opposed directions, as indicated on the plans.

The internal circuitry of a detector unit shall be potted in a semi-flexible compound for moisture resistance.

The standard operating amperage shall be less than 6 A.

Internal circuitry shall prevent electrical output due to steady state ambient light.

The confirmation beacon shall be a weatherproof floodlight fixture with a 150 W long life floodlight.

- (d) Light Detector Amplifier. The detector amplifier shall be a solid state design.

The detector amplifier shall have at least two channels and the capability of interfacing with another detector amplifier for channel expansion.

The detector amplifier shall have LED indicator lights to indicate power on, light energy being received, and channel called.

The detector amplifier, when actuated, shall continue to operate for at least six seconds after any interruption of light energy.

The detector amplifier shall sustain no permanent damage when subject to a transient produced by the discharge of a 10 microfarad capacitor charged to 600 V and applied to the AC line.

## SECTION 1073. CONTROLLER

**1073.01 Traffic Actuated Solid State Digital Controller.** A traffic actuated solid state digital controller shall be according to NEMA Standards for Traffic Control Systems, TS 1. Additionally, the controller shall be of digital design having eight independent phases and four overlap phases and shall be according to the following:

- (a) Definitions.

- (1) Anti-backup. A programmable controller logic function inhibiting a call on a leading left turn phase (1, 3, 5 or 7) from being served prior to crossing the barrier if the opposing through phase (2, 4, 6, or 8) is on, and thus avoiding left turn trap.
- (2) Minimum Red Indication (Red Revert). Provision within the controller to assure a minimum RED signal indication in a phase following the YELLOW CHANGE interval of that phase.
- (3) Offset. The time relationship expressed in seconds or percent of cycle length, determined by the difference between the starting point of the coordinated phase green and a system reference point.
- (4) Phase. The green, change, and clearance intervals in a cycle assigned to any independent movement(s) of traffic.



(b) Design.

- (1) Menu Driven Programming. The controller programming software shall utilize a menu structure displayed on a screen. The software shall display on one screen any phase associated parameter for all eight independent phases. The controller shall be capable of being programmed from the front key panel.
- (2) Electrically Erasable Programmable Read Only Memory (EEPROM) Data Storage. All controller programming data shall be retained utilizing EEPROM technology.
- (3) RS 232 Connector. The controller shall be provided with a RS 232 connector to interface with a peripheral device.
- (4) Internal Time Base Coordination. The controller unit shall have internal time base coordination as specified in Article 1073.01(c) (1).
- (5) Internal Preemption Feature. The controller unit shall preempt the signal according to Article 1073.01(c) (2).

(c) Functions.

(1) Internal Time Base Coordination.

The controller shall contain a sufficient memory to retain and implement the following programs and shall be manually programmable by a user from the front panel:

- a. At least four cycle lengths, four splits, and three offsets.
- b. 16 day programs.
- c. ten week programs.
- d. 30 special event programs.
- e. Automatic daylight savings and leap year adjustments.

The controller shall contain a calendar/clock that can be readily set to the nearest week, day, hour, minute, and second of the year. The clock shall use the power line frequency as a time base, and shall use a rechargeable battery powered, temperature compensated oscillator when power is interrupted. The capacity of the battery shall be sufficient to provide 100 consecutive hours of standby operation after 48 hours of normal operation. The clock accuracy shall be 0.005 percent or better when it is on standby power.

The controller shall provide a split interval for every phase of the controller. Phase split time shall be entered directly in percent of cycle

length or in seconds. The yield and force-off points shall be calculated automatically.

The controller shall have the capability to omit any phase during any program. This feature shall be internal to the controller and shall be selectable by the user from the front panel.

The offset reference point shall be at the beginning of the coordinated phase green. The offsets shall be in seconds or percent of cycle length and shall be calculated automatically when the cycle length is changed.

The controller shall have built-in diagnostics to detect both coordination and hardware failures. In case the coordination is not functioning, the controller shall revert to the free operation mode.

The controller shall provide real time display of its stored coordination information. The display shall be easily readable outdoors. The controller shall display the following data:

Coordination parameters.

Clock data (week of year, day of week, hour, minute, and second).

Current operational status.

The controller shall upload and download the complete coordination settings.

- (2) Internal Preemption Feature. The controller shall implement up to six preemption plans according to a preset priority. The method of activation used in preemption shall be equipped with a fail safe feature.
- (3) The controller shall have the following features.

The controller program shall include the option of single entry or dual entry mode of operation.

The overlap phases shall be programmable from the front panel or by a method approved by the Engineer.

The controller shall cross switch detectors from a left turn phase to an associated through phase according to NEMA dual ring operation.

The controller shall interface internally with the transceiver of the same manufacture.

The controller program shall include an anti-backup feature.

The controller shall have a programmable minimum RED indication (red-revert) feature of up to 9.9 seconds.

**1073.02 Flasher Controller.**

- (a) Flasher. The flasher shall be NEMA type 3 and be according to NEMA Standards for Traffic Control Systems, TS 1. LED indicators shall be provided to track the flasher output.
- (b) Housing. The flasher shall be enclosed in a weatherproof, cast aluminum cabinet of adequate size. One 15 A circuit breaker shall be provided for the incoming power line.

**1073.03 Transceiver.** A transceiver shall be microprocessor based and shall be according to NEMA Standards for Traffic Control Systems, TS 1 and the following:

- (a) Design. The transceiver shall provide the following:

- Frequency shift keying or time division multiplexing techniques.
- Half duplex or full duplex communications.
- Parity and error checking diagnostics to assure transmission and reception of valid data at 1200 baud minimum.
- Keyboard entry of system address from the front panel.
- Transmitter frequency stability over the NEMA operating temperature range of  $\pm 5$  Hz.

- (b) Functions.

- (1) The transceiver shall be capable to receive the following command data from a master controller and convey them to the local controller:

- Cycle lengths, offsets and splits
    - Special functions
    - Coordinated or free mode
    - A systemwide sync

- (2) The transceiver shall monitor the status of the following functions and transmit the information to a master controller:

- Local controller phase green
    - Local coordinator operation
    - Conflict Flash
    - Manual flash
    - Preemption
    - System detectors (a minimum of four) and local detectors (a minimum of eight)

- (3) The transceiver shall allow downloading and uploading of the local intersection data base. The preemptor and overlap data will not be downloaded.

- (c) Housing. The transceiver may be integral to the controller or furnished as a separate module in the controller.

**1073.04 Master Controller.** A master controller shall be microprocessor based and shall be according to NEMA Standards for Traffic Control Systems, (TS 1) and the following:

- (a) Operation Modes. The master controller shall be capable of operating in any of the following modes:
  - (1) Traffic Responsive. Pattern selection shall be based on traffic conditions measured by system detectors.
  - (2) Time of Day/Day of Week. Preprogrammed selection of patterns shall be based on time of day/day of week.
  - (3) Manual. Pattern selection shall be based on operator command.
- (b) Design
  - (1) Transceiver. The master controller shall contain a transceiver which shall provide transmission of all required pattern and command data to the local intersection controllers and shall allow reception of status and detector data from each local controller within the control area. The data rate among the master controller and the local controllers shall be 1200 baud minimum.
  - (2) In-Cabinet Modem. The controller cabinet shall contain a 2400 baud auto dial/auto answer modem. It shall accept Attention (AT) command set. The data rate shall be 2400 baud minimum.
  - (3) Telephone Line Terminal. The controller cabinet shall be provided with an outdoor network interface for the termination of the telephone service. It shall be mounted to the inside of the cabinet suitable to provide access for the termination of the telephone service and shall be equipped with a standard three electrode heavy duty gas tube surge arrester.
  - (4) Surge Protection. The controller cabinet shall be equipped with surge suppressers and noise filters for the telephone line and the modem's power receptacle. These shall be three stage variety containing avalanche diodes, metal-oxide varistors and gas tube arrestors.
  - (5) RS-232 C Interface. The master controller shall be equipped with two RS-232C interfaces for external communication with a remote personal computer and with a local device such as a portable personal computer or a printer.
  - (6) Keypad Data Entry and Front Panel Display. The master controller shall be programmable via a front keypad entry. A front panel display shall be provided on the master controller for operator monitoring of input values and output commands including:

Parameter values  
Current operating status  
Pattern command status  
System sensor activity  
Cycle synchronization  
Local controllers and system detectors operation status

(c) Functions.

(1) Operational Capacity

- a. Number of Local Controllers. The master controller shall have the capacity to command and supervise a minimum of 24 local controllers.
- b. Number of System Detectors. The master controller shall have the capacity to monitor at least 32 sampling detectors for all controlled intersections and up to 16 sampling detectors for a single intersection. The detectors used as sampling detectors shall be selectable from dedicated sampling detectors or local intersection detectors in any combination.
- c. Number of Timing Plans and System Commands. The master controller shall be capable of implementing a minimum of 30 timing plans. Each plan shall consist of a combination of cycle length, offset, and split. The master controller shall be capable of a minimum of four system commands including the commands for controller free or coordinated operation and for controller MUTCD flash operation.
- d. Number of Program Events. The master controller shall be capable of providing a minimum of 150 program events. A program event shall consist of a selected time of day, day of the week, and week of the year for which a timing plan, out of a minimum of 30 timing plans, shall be put into effect.
- e. Number of Logged Events. The master controller shall be capable of logging a minimum of 100 events under the buffer(s) with a time and date stamp for each event. This data shall be stored in the master controller and retrievable through the remote monitoring microcomputer.

(2) Operation Modes.

- a. Traffic Responsive Operation. Pattern selection shall be based on user selectable validated volume, occupancy, or concentration data obtained from system detectors to compute the following functions:

Level of arterial traffic  
Directionality of arterial traffic  
Ratio of a set of detectors to a second set of detectors

## Ratio of side street to arterial traffic

Preferential and/or hierarchical transfer of patterns shall be accomplished via programmable user-specified threshold values.

- b. Time of Day/Day of Week Operation. The master controller shall be according to the internal time base coordination as specified in Article 1073.01 (c)(1). It shall be possible to select any system pattern from the master controller on a preprogrammed time of day/day of week basis with automatic daylight savings and leap year adjustments. In addition, it shall be possible to specify the following on a time of day/day of week basis:

- Special function system commands
- Crossing artery synchronization
- Traffic responsive computation period
- System detector and speed report interval

- c. Manual Operation. Pattern selection shall be based on operator command.

(3) Remote System Controlling, Reporting, Monitoring, and Diagnosing.

The master controller shall be capable of being programmed and monitored from a remote site through a computer program running under Microsoft Disk Operating System (MS DOS™ MS DOS™) or under Windows Operating System on a IBM compatible personal computer (PC) either stand alone or a station in a local area network (LAN). The IBM compatible PC shall utilize a 486 series microprocessor or a next generation of microprocessor. The programming and monitoring from the remote site shall include the following functions:

- a. Remote System Control. The master controller shall enable upload and download of all master programming as well as local controller programming.
- b. Remote System Reporting.
  - 1. System Status Report. When requested a system status report shall be generated. The report shall indicate current operating mode and pattern for local controllers.
  - 2. System Failure Report. This report shall indicate the off line local controllers and the failure time and mode. The master controller shall communicate the local controller faults to the remote site.
  - 3. System Detector Failure Report. All failed system detectors shall be listed on this report.

4. System Detector Report. The volume and occupancy data from any of the system detectors, tabulated by 15 minute intervals for a 24 hour period shall be included on this report.
  5. System Fault Alarms. The master controller shall have the capability of programmable fault reporting by dialing out to assigned telephone number(s). A minimum of three levels of programmable alarms shall be provided.
  6. System Operation Report. This report or an equivalent shall indicate the time of changes in operation mode and the timing patterns for the past 48 hours.
- c. Remote System Monitoring.
1. Number of Systems Monitored. The remote system software shall be capable of monitoring a minimum of 99 separate systems.
  2. Data Compatibility Between the Software Versions. Data from earlier versions of the remote system monitor software shall be compatible with or easily translatable for use in newer version upgrade. Manual reconstruction of data base shall not be required with each upgrade. All software located in controllers and master controllers, which are currently in use in the field and new, shall be compatible with all current or new versions of the remote system monitor software. The version of the software for all master and local controllers shall be uploaded and viewed during each upload and download. As part of a data base set up, the remote system monitor software shall not require master and local controller software versions to be manually programmed except for the master and local controller model numbers or types. All firmware changes made at any master or local controller shall be transparent to the remote system monitor software.
  3. Intersection and System Graphics. The supplier of the master controller shall create intersection and system graphic displays and program all software parameters for each intersection to be monitored through the master controller, including complete viewing and control capabilities. Each intersection display and system display shall show a mode of operation, that is, traffic responsive, time of day, or free, and the timing plan in effect for the coordinated operation, that is, cycle length, split, and offset.

The intersection displays shall be an accurate graphical representation of the intersection geometry, lane configuration, signal phasing, and detector layout. The display shall contain the correct alignment of the crossing streets and include the correct number and types of lanes. Depending on the

intersection geometry, the display shall show left turn lanes, dual left turn lanes, multiple through lanes, and right turn lanes. The display shall contain indicators for all used controller phases, associated pedestrian phases, and overlap phases, and for local detectors actuation, and system detectors actuation.

The system displays shall be an accurate graphical representation of the signal system. The system display shall contain all system intersections. The display shall contain indicators for all used phases at all intersections and system detectors actuation.

d. System Diagnostics.

1. Local Controller Diagnostic. At a minimum the master controller shall diagnose and report local controller flash fault by reporting the conflict monitor fault logging information for the current fault.
2. System Detector Diagnostic. Each system detector shall be monitored for constant calls, absence of calls, or erratic output. Diagnostic values shall be user programmable for all detectors on a system basis. System detectors which fail the diagnostic test shall be automatically deleted for volume and occupancy calculations. The event of failure occurrence shall be stored for reporting. Upon resumption of satisfactory operation, detectors shall automatically resume input to volume and occupancy calculations.

## SECTION 1074. CONTROL EQUIPMENT

**1074.01 Digital Time Switch.** The digital time switch shall be according to Section 2 and Article 4.2.2 of NEMA Standards for Traffic Control Systems, TS 1, and the following:

- (a) Functions. The digital time switch shall be capable of opening and closing a circuit at specific times of a day and shall be capable of omitting circuit operation during certain days of the week. It shall be possible to set any opening or closing to the nearest minute, the open period for as short as 90 minutes and the close period for as short as 30 minutes. It shall also be capable of providing four "on" and four "off" operations in each 24 hour period. All settings shall be field programmable using a key pad.
- (b) Designs. The digital time switch shall contain a precise clock based on a seven day program, setable to the nearest second of the week, day, hour, and minute. The 60 Hz power line frequency shall be the basic time reference for the clock. The clock shall automatically adjust for daylight savings and leap years.



The digital time switch shall have a battery back-up feature to protect against loss of timing in case of a power failure. During power failure, the battery operation shall keep the unit in time for a period of up to 100 hours. The unit clock accuracy shall be 0.005 percent or better when it is on battery power and shall assume normal operation upon resumption of power.

- (c) Special Features. The digital time switch shall include the following light emitting diodes indicators to confirm the applicable status outputs:

- (1) ON - OFF.

- (2) LINE POWER - BATTERY.

A time of day display shall be provided which is easily readable outdoors. Each unit furnished shall be labeled as to the function it controls.

#### **1074.02 Pedestrian Push-Button.**

- (a) Housing. The housing shall be made of aluminum alloy and furnished with suitable mounting hardware. The front of the housing shall have flexible cover so the push-button detector will be freezeproof.
- (b) Push-button. The push-button shall be made of brass or other nonrusting material and shall be of sturdy design.
- (c) Contacts. The contacts shall be entirely enclosed and insulated from the push-button housing. The contacts shall be normally open and shall be closed when the push-button is pressed, restoring immediately to a normal open position when released.
- (d) Sign. The pedestrian information sign shall be according to the MUTCD. The legend on the sign shall either be all words or a combination of words and symbol to match the pedestrian signal. The sign base shall be sheet aluminum according to Article 1090.02.

#### **1074.03 Controller Cabinet And Peripheral Equipment.**

- (a) Cabinet. A controller cabinet shall house a controller and peripheral equipment by providing a secure space and by guarding against inclement weather. The cabinet shall be made of an aluminum alloy and shall be of sturdy construction. Only one cabinet shall be permitted at one intersection for all traffic control equipment.

- (1) Cabinet Type. The cabinet specified on the plans shall be determined on the basis of the average volume of the control equipment to be installed in the cabinet. The various types of cabinets shall meet the following:

Type	Approx. Volume cu m (cu ft)	Police Door	Mounting	Ventilation	Remark
I	Reserved				
II	0.14 (5.0)	Yes	Post Top	Filtered Air Intake and One Thermo-Statically Controlled Fan	
III	0.33 (11.5)	Yes	Ground Mount	Filtered Air Intake and One Thermo-Statically Controlled Fan	For Traffic Actuated Controller
IV	0.82 (29.0)	Yes	Ground Mount	Filtered Air Intake and Two Thermo-Statically Controlled Fans	For Traffic Actuated Controller. Back Panel with Minimum 12 Load Switch Positions.
V	1.25 (44.0)	Yes	Ground Mount	Filtered Air Intake and Two Thermo-Statically Controlled Fans	For Traffic Actuated Controller. Back Panel with Minimum 12 Load Switch Positions.

- (2) Weather Resistant Requirements.

- a. Heavy-duty Door Gasket. Heavy-duty gaskets shall be provided around door openings to make a weather-tight seal for the protection of the enclosed equipment.
- b. Caulking of Cabinets. Ground mount cabinets shall be caulked along the entire perimeter of the base with a waterproof, nonhardening exterior compound prior to setting on the foundation to ensure a water, dust and insect proof seal.
- c. Screened Vent. A standard furnace filter shall be mounted on the inside of the cabinet door and shall be designed to prevent the entrance of insects, blowing rain and snow. It shall be securely attached to the cabinet and shall be removable by simple tools to permit cleaning and replacement.
- d. Cabinet Exterior. The cabinet surface shall be smooth, free of marks and scratches and provide an unpainted aluminum finish.

- (3) Cabinet Design.

- a. Multiple Door-Stop. The cabinet front door shall be capable of being held at various angles by a stop-and-catch mechanism.
  - b. Door Handle. The door handle shall rotate outward from the locked position. The operation of the handle shall not interfere with the key, police door or any other cabinet mechanism.
  - c. Door Locks and Keys. The front door shall be equipped with a standard or a tumbler lock and the police door shall be provided with a police type lock. The front door lock shall not open by a standard police key. Additionally, two sets of keys shall be provided with each cabinet.
- (4) Lightning Protection. The cabinet shall be provided with lightning protection. Lightning arrester leads should be kept as short as possible and ground should be made directly to the cabinet wall or ground plate as near as possible to the object being grounded. All lightning arresters shall be tested and certified as meeting this specification by an independent testing laboratory. One copy each of the full testing report shall be submitted to the Engineer.
- a. AC Input for Solid State Controller. The arrester shall be capable of withstanding a minimum of ten repeated 20,000 A (8 x 20 microsecond wave form) surges, and shall have initial follow current limiters (resistive elements), a series filter network (rated 10 A), and a high speed clamping component. The inductance shall be a minimum of 200 microhenries and the high speed clamp shall have a maximum response time of five nanoseconds. The maximum clamp voltage shall be 380 V at 20,000 A.
  - b. Detector Loop. The shield and the drain wire of the lead-in cable shall be grounded at the controller cabinet end to the closest cabinet wall or ground plate. At the other end, the shield and the drain wire shall be insulated to prevent possible grounding.
  - c. Interconnection, 120 VAC. A replaceable spark gap gas type cartridge shall be provided between each incoming conductor and ground.
  - d. Interconnection, DC or Low Voltage Balanced Line. The unit shall be capable of withstanding a minimum of 100 repeated 2,000 A (8 x 20 microsecond wave form) surges. The response time shall not exceed 100 nanoseconds with a duty cycle of 0.01 percent for 100 A surge. The voltage clamp shall be 30 V.
- (5) Miscellaneous Cabinet Function Requirements.
- a. Signal Flash in Absence of Conflict Monitor. The cabinet shall contain circuitry that will place signal into flashing mode of operation if the conflict monitor is disconnected.

- b. **Thermostatically Controlled Exhaust Fan.** The cabinet shall be equipped with a thermostatically controlled exhaust fan. The fan shall have a minimum air delivery capacity of 2.8 cu m/min (100 cfm) and shall be mounted on self-lubricating ball bearings. The thermostat control shall be adjustable between 33 °C (91 °F) and 45 °C (113 °F) and shall be set to turn the fan on at 35 °C (95 °F).
- c. **Power Outlet and Light Fixture.** Within the cabinet shall be provided a grounded three wire, 120 V, ground fault interrupter duplex outlet and a cabinet-door-switchable light fixture with a standard incandescent soft light bulb of 55 to 70 W.
- d. **Signal Control Switches.** The switches shall be provided in the controller cabinet for the following mode of operation:
  - Controller: ON-OFF
  - Controller: STOP TIME-RUN-REMOTE
  - Signals: NORMAL-MUTCD FLASH (with controller on)

The switches shall be provided in the police door compartment for the following mode of operation:

- Signals: ON-OFF (The switch operation shall not depend on the position of AUTO-FLASH switch.)
- Signals: AUTO-FLASH (with controller in stop time)
- Signals: AUTO-MANUAL

(b) **Peripheral Equipment.**

- (1) **Conflict Monitor.** A conflict monitor shall be according to NEMA Standards for Traffic Control Systems, TS 1, including the specified monitoring of signal indication conflict, absence of RED signal voltage, and voltage. The conflict monitor shall be according to the following:
  - a. **Number of Programmable Channels.** The conflict monitor shall have either 12 or 18 fully programmable channels according to NEMA Type 12 or Type 18 unit respectively. The number of channels shall be sufficient to monitor all of the used vehicular phases, associated pedestrian phases, and overlap phases.
  - b. **Simultaneous Dual Color Conflict.** The conflict monitor shall detect simultaneous display of two separate colors in each signal face except the simultaneous display of "circular red" and "green turn arrow", or "circular red" and "yellow turn arrow" as signal indication conflict.
  - c. **Operation Upon Conflict Detection.** Upon detection of signal indication conflict, absence of RED signal voltage or specified voltage deviation, the monitor shall place the signals into emergency flashing operation. The controller shall stop timing in the condition that existed at the moment of conflict and shall remain

in stop time, except for the emergency flash caused by specified voltage deviation, until reset by maintenance personnel. The monitor channel indicators shall display the fault status and the field output status at the time of the failure.

- d. Fault Log. The conflict monitor shall store a minimum of last 20 fault status and the corresponding field output status with the date and time stamps in a non-volatile memory.
  - e. Liquid Crystal Display (LCD). The conflict monitor shall simultaneously indicate the field output status for all the programmed channels on the LCD. When interrogated, the conflict monitor shall indicate the stored fault status on the LCD.
  - f. Channel to Phase Association. The conflict monitor channels shall be assigned the same channel numbers as the phase they are monitoring.
- (2) Load Switches. All signal lamp circuits shall be opened and closed by solid state load switches according to NEMA Standards for Traffic Control Systems, TS 1. Load switches shall have a rated load capacity of 15 A minimum within the temperature range of -34 °C (-29 °F) and 74 °C (165 °F). A sufficient number of load switches shall be furnished with each controller so the maximum load per circuit will not exceed 900 W. The load switches shall be provided with LED indicator lights to indicate the controller output status.
- (3) Panel and Terminal Facilities. Panel and terminal facilities shall be according to NEMA Standards for Traffic Control Systems, TS 1. Additionally, the panel and terminal facilities shall be according to the following:

The panel board shall be provided on the back wall of the controller cabinet containing local switch sockets and terminal facilities. The load switch sockets shall be positioned so as to accept various NEMA load switches with different sizes of heat sink housings.

The back panel for the cabinet Types IV and V shall contain at a minimum: 12 load switch wired sockets and four flash transfer relay wired sockets. To prevent the conflict monitor from detecting absence of RED voltage on the spare wired sockets, the RED output pin (pin 1) shall be wire jumpered to 120 VAC (pin 3).

One circuit breaker rated 10 A shall be provided for the control equipment and another circuit breaker rated 40 A shall be provided for the signal load.

The field wire terminals shall be located at least 250 mm (10 in.) above the bottom of the controller cabinet.

- (4) Flasher Unit and Flasher Relay. A flasher unit shall be according to NEMA Standards for Traffic Control Systems TS 1, for NEMA Type 3 Flashers, (15 A, dual circuit) and the following:

Each controller shall be provided with one or more jack mounted flasher units and the necessary relays. The flasher and flasher relay shall not operate at more than 85 percent of its rated load.

In conflict monitor triggered flash, all three color signal indications shall flash in red, all signals controlling the same approach of an intersection shall flash simultaneously, and the pedestrian signal faces shall be dark.

Automatic changes from stop-and-go to flashing operation and vice versa shall begin at a predetermined interval according to the MUTCD 2000, Section 4D-12.

It shall be possible to remove the controller and its associated components from the cabinet with the flasher continuing in operation.

## **SECTION 1075. WIREWAY AND CONDUIT SYSTEM**

### **1075.01 Gulfbox Junction.**

- (a) Surrounding Material. The material surrounding the gulfbox shall be Class SI concrete and/or CA 6 Granular material according to Sections 1020 and 1004.
- (b) Cover. The gulfbox cover shall be either cast iron or composite concrete according to Article 1088.07 or Article 1088.05, respectively.
- (c) Cast Iron Box. The box shall be made of cast iron according to AASHTO M 105, Class 30 or better. The box shall be bottomless and 375 mm (14 3/4 in.) long, 300 mm (12 in.) wide and 200 mm (8 in.) deep.
- (d) Composite Concrete Box. The box shall be composite concrete according to Article 1088.05. The box shall be bottomless and 375 mm (14 3/4 in.) long, 375 mm (14 3/4 in.) wide and 320 mm (12 3/4 in.) deep.

### **1075.02 Pulling Pedestal.**

- (a) Enclosure. The pulling pedestal enclosure shall be a single door design, fabricated from 3 mm (0.125 in.) thick Type 5052-H32 aluminum. The enclosure door frame shall be double flanged out on all four sides. All external hardware shall be stainless steel. The enclosure shall have a NEMA 3R rating. Where no dimensions are indicated on the plans, the cabinet shall be sized to adequately house all required components, cables, and fully comply with NEC pull box sizing requirements.

The door shall be constructed from the same material and thickness as the cabinet. The door shall be equipped with a three point latching mechanism with nylon rollers at the top and bottom. The door handle shall be stainless steel and shall have a minimum diameter of 13 mm (1/2 in.) and have a padlock provision. The door shall be sealed with a neoprene gasket. The door hinge shall be a heavy gauge continuous hinge with a 6 mm (1/4 in.) diameter stainless steel hinge pin. The hinge shall be secured with stainless steel carriage bolts and stainless steel nuts and locknuts.

Ground Lug. The enclosure shall have a ground lug suitable for installation of a 2/0 ground wire.

- (b) Terminal Strips. The enclosure shall have an equipment mounting panel made of 6 mm (1/4 in.) minimum non asbestos inorganic nonconduction material which shall be drilled and tapped for front mounting of the equipment. The panel shall be easily installed and removed from the front of the cabinet. Terminal blocks shall be 600 V, with barrier strips between poles. The terminal blocks shall be constructed so wires can be attached without the need for terminal lugs. Terminal blocks shall be sized to accept No. 14 through No. 2/0 cables and shall be made of copper. All cable and connections shall be in front of the panel.
- (c) Finish. The cabinet shall be prepared inside and outside before painting, or as otherwise recommended by the paint manufacturer and approved by the Engineer. The cabinet shall then receive two sprayed coats of white polyamide epoxy primer with a corrosion inhibitor applied inside and outside to all surfaces.

The primer shall have a solid content by volume of not less than 65 percent  $\pm$  3 percent and each coat shall be applied to a thickness of 75-125  $\mu$ m (3-5 mil).

The interior and exterior, (all surfaces), shall then receive one final coat of silicone alkyd enamel paint. The finish paint shall be applied to a thickness of 40-60  $\mu$ m (1.5-2.5 mils).

The color of the finish paint shall meet ANSI standards No. 70 Sky Gray.

The finish shall be applied according to the paint manufacturer's recommendations. The manufacturer shall certify, in writing that the finish has been applied properly.

Submittal data submitted for approval shall address the requirement for the paint manufacturer's certification and shall include a standard, single source paint warranty by the paint manufacturer or the controller manufacturer to the Department.

SECTION 1076. WIRE AND CABLE

1076.01 Multi-Conductor Power Cable.

- (a) General. The cable shall be an assembly of insulated power conductors, plus an insulated ground wire cabled according to UL 1277 with fillers and binder tape, and with a jacket overall. The cable shall be 90 °C (194 °F) dry and 75 °C (167°F) wet. The conductors and ground conductor shall be the required insulated conductors.

All conductors in the assembly may be either coated, (thinned), or uncoated copper, except all conductors of a given cable type for the project shall be of the same type and be according to Article 1066.02.

- (b) Ground Conductor. The insulated ground conductor shall correspond to the insulated conductor size as indicated in the following table:

Insulated Conductor Size, AWG	Insulated Ground Conductor Size (AWG) Min.
8	10
6	8
4	8
2 thru 2/0	6
3/0 thru 4/0	4

- (c) Insulation. Each conductor shall be insulated with flame retardant ethylene-propylene rubber (EPR) insulation conforming to UL 44, ICEA S-68-516, which shall be heat, moisture, chemical and flame resistant. These conductors shall have an average minimum insulation thickness as indicated in the following table:

Insulation Thickness

Conductor Size, AWG	Minimum Insulation Thickness
8 thru 2	1.1 mm (45 mil)
1 thru 4/0	1.4 mm (55 mil)

Minimum insulation thickness at any point shall be 90 percent of the average insulation's thickness listed in the table above.

Conductor insulation shall be color coded. Neutral conductors shall be color coded white. Three conductor cables (plus ground) for use on single phase systems shall be color coded one black, one red, and one white. Two conductor (plus ground) cables for use on single phase systems shall be color coded one black and one white when used on phase-to-neutral systems, and one black and one red when used on phase-to-phase systems. Three conductor cables for use on three phase systems shall be color coded one black, one red, and one blue. Ground conductors shall be color coded green. Color coding for other cable configurations and systems



shall be as directed by the Engineer. Color coding shall be made by means of impregnating the insulation with the color. The coloring process shall impregnate a color which is fade resistant. Color coding via striping, lettering, painting, or other means will not be acceptable for these systems. Each conductor shall be marked by printing in a contrasting color the size, voltage rating, type of insulation, and required UL information.

- (d) Overall Jacket. The cable assembly shall have chlorinated polyethylene (CPE) jacket applied over the assembly. The jacket shall meet the requirements of ICEA S-68-616, Part 4 and the sunlight resistant requirements of UL Standard 1277. The jacket shall be marked by means of surface ink printing indicating manufacturer, number of conductors, size, voltage rating, and required UL information.
- (e) Quality Control. The cable shall be manufactured and tested according to ICEA S-68-516 NEMA WC 8.

Manufacturer's information submitted for approval shall include product and other data sufficient to verify compliance with all specified requirements. The cable shall be shipped to the site in wood-lagged reels or other equivalent means as approved by the Engineer. Each reel shall be tagged.

#### **1076.02 Fiber Optic Cable.**

- (a) General. The outside plant, all-dielectric, loose-tube fiber optic cable shall be according to the ANSI, Electronics Industries Association (EIA) and Telecommunications Industries Association (TIA) for the multimode cable of the size specified, and the following:
- (b) Fiber. Each fiber shall be multimode, graded index, and a specified nominal diameter (core/clad). Each fiber attenuation shall not exceed 3.5 dB/km nominal, measured at room temperature at 850 nm and the bandwidth shall be a minimum of 160 MHz/km at 850 nm. The fibers and the buffered tubes containing loose fibers shall be color coded according to the following industry standard color coding scheme.

Fiber No./ Tube No.	Color	Fiber No./ Tube No.	Color
1	Blue	7	Red
2	Orange	8	Black
3	Green	9	Yellow
4	Brown	10	Violet
5	Slate	11	Rose
6	White	12	Aqua

- (c) Cable Construction.

- (1) Central Member. The central member of the cable shall be a glass reinforced plastic rod designed to prevent buckling of the cable.

- (2) Fillers. Dielectric fillers may be included in the cable core where needed to lend symmetry to the cable cross-section.
  - (3) Buffer Tube Gel. Each buffer tube shall be filled with a non-hygroscopic, non-nutritive to fungus, electrically non-conductive, homogeneous gel. The gel shall be free from dirt and foreign matter and be readily removable with conventional non toxic solvents.
  - (4) Cable Core Gel. In addition to the buffer tube gel properties the gel filling the cable core interstices shall be water blocking.
  - (5) Ripcord. The cable shall contain at least one ripcord under the jacket.
  - (6) Tensile Strength Member. The cable tensile strength shall be provided by high tensile strength aramid yarns.
  - (7) Cable Jacket. The cable shall be sheathed with medium density polyethylene. The polyethylene jacket shall be a consistent thickness having a minimum acceptable average thickness of 1.4 mm (.056 in.). The polyethylene shall contain carbon black to provide ultraviolet light protection and shall not promote the growth of fungus.
  - (8) Cable Marking. The cable jacket or sheath shall be marked with the manufacturer's name, the words "Optical Cable", year of manufacture, and with sequential meter (foot) marks.
- (d) Tensile Load. The cable shall withstand a maximum pulling tension of 2700 N (600 lb) during installation, short term and 600 N (135 lb) upon installation, long term.
- (e) Temperature Range. The shipping, storing, installing, and operating range of the cable shall be -30 to 70 °C (-22 to 158 °F).
- (f) Cable Performance Tests. The cable shall be according to the standard Fiber Optic Test Procedure for the following performance measures.
- Fluid Penetration
  - Compound Drip
  - Compressive Loading Resistance
  - Cyclic Flexing
  - Cyclic Impact
  - Tensile Loading and Bending
- (g) Quality Assurance.
- (1) Proof Tested. Each optical fiber shall be proof tested by the fiber manufacturer at a minimum stress of 350,000 kPa (50 kips/sq in.).
  - (2) Attenuation Tested. Each optical fiber shall be 100 percent attenuation tested by the cable manufacturer and the attenuation of each fiber shall be provided with each cable reel.

(h) Packaging.

- (1) Cable Ends. The top and bottom ends of the cable shall be available for testing. The cable ends shall be sealed to prevent moisture ingress.
- (2) Cable Label. Each cable reel shall have a durable weatherproof label which shows the actual length of the cable on the reel and the attenuation of each fiber expressed in dB/km.

**1076.03 Span Wire and Tether Wire.**

- (a) Wire. The span wire shall be 9 mm (3/8 in.) nominal diameter, seven strand, zinc-coated steel wire according to ASTM A 475, Utilities Grade or better. The tether wire shall be 6 mm (1/4 in.) nominal diameter, seven strand, zinc-coated steel wire according to ASTM A 475, High Strength Grade or better.
- (b) Accessories. All accessories, except cable hangers, shall be made of galvanized steel or noncorrosive material. Cable hangers shall be made of exterior black nylon or steel. The tensile strength of all accessories, except cable hangers, shall be equal to or greater than the tensile strength of the wire with which they are used. Thimble-eye bolts shall be 15 mm (5/8 in.) in nominal diameter and be according to ASTM A 307.

**1076.04 Electric Cable – Signal, Lead-in, Communication, and Service.**

- (a) Signal Cable. The signal cable shall transmit 120 VAC to signal heads, pedestrian heads and internally illuminated signs, or transmit 24 VDC to pedestrian push-buttons. The signal cable shall be according to IMSA No. 19-1 or IMSA No. 20-1. The tracer color lines shall be extruded with the insulation extrusion. The conductors shall be copper, solid or stranded, and No. 12 or 14 AWG.
- (b) Lead-in Cable Single-Pair. The lead-in cable single-pair shall transmit and receive the vehicle detection signal between the loop detector unit and the detector loop. The lead-in cable single-pair shall be according to IMSA No. 50-2. The conductors shall be stranded tinned copper, and No. 14, 16 or 18 AWG.
- (c) Communication Cable and Lead-in Cable Multipair
  - (1) Conductors. The fully annealed tinned copper shall be according to ASTM B-33. The stranded conductors shall be according to ASTM B-8 for concentric stranding or ASTM B-174 for bunch stranding. The conductors shall be No. 16 or 18 AWG, 3, 6, 9 or 12 pair.
  - (2) Insulation. The polyethylene insulation shall be according to ASTM D-1248, Type 1, Grade 4, Class A or B. The minimum insulation thickness at any point shall not be less than 90 percent of average insulation thickness of 0.51 mm (20 mil).

Conductor Insulation Color Code. All pairs shall have one conductor with black color insulation and one conductor with insulation of another unique non-black color.

- (3) Shielding. The conductors shall be in twisted pairs and each pair shall be individually shielded. The shielding shall be aluminized mylar or polyester. One stranded tinned copper drain wire shall be provided.

The shielding shall be 100 percent effective by providing a metal-to-metal contact between adjacent wraps. The capacitance measured between conductors shall be 100 (30) picofarads or less per meter (foot). The capacitance measured between one conductor and another conductor connected to the shield shall be 180 (55) picofarads or less per meter (foot).

- (4) Jacket. The jacket shall be polyvinyl chloride according to IMSA No. 39-2, or polyethylene according to IMSA No. 40-6.

- (5) Identification. Each shipping length of cable shall show the name of the manufacturer, the year of manufacture, the voltage rating, the U.L. listing mark, and the conductor size in AWG. This information shall be applied every 0.61 m (2 ft) or less to the outer surface of the jacket by indent printing. The electric cables furnished shall not be dated more than five years prior to the time of installation.

- (6) Sampling, inspection and acceptance. The cable shall be according to IMSA No. 39-2, or IMSA No. 40-6.

- (d) Service Cable. The stranded copper, cross linked polyethylene insulated service cable shall be according to Articles 1066.02 and 1066.03.

## SECTION 1077. POST AND FOUNDATION

**1077.01 Traffic Signal Post.** The traffic signal post shall be designed to support the traffic signal loading shown on the plans. The design and fabrication shall be according to the Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, as published by AASHTO.

- (a) Post. The post shall be made of steel or aluminum and have an outside diameter of 115 mm (4 1/2 in.). The post shall be threaded for assembly to the base. Aluminum posts shall be according to the specifications for Schedule 80 aluminum pipe. Steel posts shall be according to the specifications for Schedule 40 steel pipe.
- (b) Base. The base of a steel post shall be cast iron. The base of an aluminum post shall be aluminum. The base shall be threaded for the attachment to the threaded post. The base shall be approximately 375 mm (15 in.) high and 335 mm (13 1/2 in.) square at the bottom. The bottom of the base shall be designed to accept four 16 mm (5/8 in.) diameter anchor rods evenly

spaced in a 320 mm (12 1/2 in.) to 330 mm (13 in.) diameter circle. The base shall be true to pattern, with sharp clean cutting ornamentation, and equipped with access doors for cable handling. The door shall be fastened to the base with stainless steel screws. A grounding lug shall be provided inside the base.

The aluminum post and base shall be drilled at the third points around the diameter and 6 mm (1/4 in.) by 50 mm (2 in.) stainless steel bolts shall be inserted to prevent the post from turning and wobbling.

- (c) Anchor Rods. The anchor rods shall be a minimum of 16 mm (5/8 in.) in diameter and 400 mm (16 in.) long and shall be according to Article 1006.09. The anchor rods shall be threaded approximately 75 mm (3 in.) at one end and have a bend at the other end. The first 125 mm (5 in.) at the threaded end shall be galvanized. One each galvanized nut and washer shall be furnished with each anchor rod.
- (d) Finish. The steel post and the cast iron base shall be either hot dipped galvanized in according to AASHTO M 111 or shop painted with one coat of primer and two coats of yellow enamel according to Section 851. If the post and the base are threaded after the galvanization, the bare exposed metal shall be immediately cleaned to remove all cutting solvents and oils, and then spray painted with two coats of an approved galvanized paint.

#### **1077.02 Pedestrian Push-Button Post.**

- (a) Post. The steel post shall be according to Article 1077.01, except the nominal size shall be 75 mm (3 in.). The Type I pedestrian push button post shall use a 75 mm (3 in.) threaded connection. The Type II pedestrian push-button post shall include two flange plates located approximately 25 mm (1 in.) above the ground level.
- (b) Finish. The post and cap shall be either hot dipped galvanized according to AASHTO M 111 or shop painted with one coat of primer and two coats of yellow enamel according to Section 851. If the post is threaded after galvanization, the bare exposed metal shall be immediately cleaned to remove all cutting solvents and oils, and then spray painted with two coats of an approved galvanized paint.

#### **1077.03 Mast Arm Assembly and Pole.**

- (a) Steel Mast Arm Assembly and Pole and Steel Combination Mast Arm Assembly and Pole. The steel mast arm assembly and pole and steel combination mast arm assembly and pole shall consist of a traffic signal mast arm, a luminaire mast arm or davit (for combination pole only), a pole, and a base, together with anchor rods and other appurtenances. The configuration of the mast arm assembly, pole, and base shall be according to the details shown on the plans.
- (1) Loading. The combination mast arm assembly and pole, and mast arm assembly and pole shall be designed to support one 36 kg (80 lb) signal

head with a projected area of 1.37 sq m (14.7 sq ft) at the free end of the mast arm, one 23 kg (50 lb) signal head with a projected area of 0.81 sq m (8.7 sq ft) mounted 3.6 m (12 ft) inward on the mast arm, one 56 kg (125 lb) signal head with a projected area of 0.71 sq m (7.6 sq ft) mounted 3.6 m (12 ft) high on the shaft, and a sign panel 750 mm x 1,800 mm (2.5 ft x 6 ft) mounted as shown on the current standard or the loading shown on the plan, whichever is greater. The design shall be according to the requirements of the current "Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" as published by AASHTO for 130 km/h (80 MPH) wind velocity.

- (2) Structural Steel Grade. The mast arm and pole shall be fabricated according to ASTM A 595, Grade A or B. The base and flange plates shall be of structural steel conforming to AASHTO M 270M Grade 250 (M 270 Grade 36) of cast steel conforming to ASTM A 27, Grade 70-36 or better. All mast arm assemblies, poles, and bases shall be galvanized according to AASHTO M 111.
- (3) Fabrication. The design and fabrication of the mast arm assembly, pole, and base shall conform to the requirements of the Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals published by AASHTO. The mast arm and pole may be of single length or sectional design. If section design is used, the overlap shall be at least 150 percent of the maximum diameter of the overlapping section and shall be assembled in the factory.

The manufacturer will be allowed to slot the base plate in which other bolt circles may fit, providing that these slots do not offset the integrity of the pole.

- (4) Shop Drawing Approval. The contractor shall submit detailed drawings showing design materials, thickness of sections, weld sizes, and anchor rods to the Engineer for approval prior to fabrication. These drawings shall be at least 430 mm x 560 mm (17 in. x 22 in.) in size and of adequate quality for microfilming.

- (b) Anchor Rods. The anchor rods shall be according to Article 1006.09 and shall be threaded a minimum of 185 mm (7 1/2 in.) at one end and have a bend at the other end. The first 250 mm (10 in.) at the threaded end shall be galvanized. Two nuts, one lock washer, and one flat washer shall be furnished with each anchor rod. All nuts and washers shall be galvanized.

#### **1077.04 Traffic Signal Wood Pole.**

- (a) Pole. Wood pole shall be full treated southern pine, Douglas fir, or western red cedar conforming to the American National Standard Specifications and Dimensions for Wood Poles. The preservative treatment shall conform to the American Wood Preservers' Association Standard C4.
- (b) Down Guy. The down guy shall consist of a guy wire and other appurtenances as shown on the plans. The guy wire shall be of 9.5 mm (3/8

in.) nominal diameter seven strand, zinc-coated steel wire conforming to ASTM A475, Utilities Grade or better. The other appurtenances shall be galvanized according to AASHTO M 232 and be according to the following:

The anchor shall have a minimum expanded area of 81,000 sq mm (125 sq in.).

The anchor rod shall have a nominal diameter of 16 mm (5/8 in.) and a minimum breaking strength of 51,200 N (11,500 lb).

The guy guard shall be 2.1 m (7 ft.) long, tapered, and made of 18 gauge steel minimum, except for sidewalk guys, the guy guards shall be made of heavy-duty plastic.

The guy wire clamps shall be three bolt and have a minimum breaking strength of 51,200 N (11,500 lb).

The dead-ends shall be made of the same material as the guy wire.

## **SECTION 1078. TRAFFIC SIGNAL HEAD**

### **1078.01 Signal Head and Optically Programmed Signal Head.**

- (a) Face. The signal face shall be of sectional design and expandable.
- (b) Housing and Door. The cast aluminum housing or door shall be according to the alloy and tensile requirements of the ITE Standards. The polycarbonate housing or door shall be made of Ultra-Violet stabilized polycarbonate resin and shall be molded in one piece with a minimum thickness of 2.25 mm (0.09 in.).

The top and bottom of each housing shall have an opening to accommodate standard 35 mm (1.5 in.) pipe fittings and brackets. The top and bottom openings shall each have an interlocking ring integral with the signal section. The locking ring shall have 72 teeth, permitting rotation of the signal section in five degree steps.

The door shall be securely attached to the housing with stainless steel hardware. All access openings shall be provided with neoprene or rubber gaskets.

- (c) Optical Unit. The optical unit shall be according to ITE Standards.

- (1) The conventional signal section shall be according to the following:

- a. Lamp. The lamps shall be an incandescent type and a minimum 85 percent Krypton filled. The lamp for a 300 mm (12 in.) section shall be nominal 135 W, 1750 lumens with a minimum average rated life of 8,000 hours (0.91 year). The lamp for a 200 mm (8 in.)

section shall be nominal 60 W, 610 lumens with a minimum average rated life of 8,000 hours (0.91 year).

- b. Reflector. The reflector shall be a parabolic silvered glass or Alzak aluminum.
  - c. Dimmer. When specified on the plans, signal dimmers shall be provided for 300 mm (12 in.) yellow signal sections. The dimmer shall allow the signal lamp to operate at full intensity under daylight conditions and to reduce proportionally to  $25 \pm 5$  percent of full intensity at night. A dimmer shall not control more than one yellow section for each direction.
- (2) The optically programmed signal section shall be according to the following:
- a. Lamp. The lamp shall be a nominal 150 W sealed beam unit having an integral reflector and a minimum average rated life of 6,000 hours (0.68 year).
  - b. Optical Limiter-Diffuser. The optical limiter-diffuser shall provide an imaging surface at focus on the optical axis for objects 275 m to 365 m (900 to 1,200 ft) distance and permit an optical masking tape to be variously applied as determined by the desired visibility zone. The optical limiter diffuser shall be provided with positive indexing means and composed of heat-resistant glass.
  - c. Objective Lens. The objective lens shall be a high resolution planar incremental lens hermetically sealed with a flat laminate of weather-resistant acrylic. The lens shall be symmetrical in outline and capable of being rotated to any 90 degree orientation about the optical axis. The projected signal indication shall be capable of being veiled anywhere within 15 degrees of the optical axis. The indication shall not result from external illumination and shall be according to the ITE Standards.
  - d. Photo Control. The photo control shall comprise an integrated, directional light sensing and regulating device interposed between lamp and line wires. The lamp intensity shall not be less than 37 percent of uncontrolled intensity at 10,000 lux (1,000 ft candles) and shall be reduced to  $15 \pm 2$  percent of maximum at less than 10 lux (1 ft candle). The response shall be proportional and essentially instantaneous to any detectable increase of illumination from darkness to 10,000 lux (1,000 ft candles) and damped for any increase from 10,000 lux (1,000 ft candles). The photo control shall be compatible with 60 Hz input and responsive within the range of 105 to 135 VAC.
- (d) Terminal Block. Each signal face shall contain a terminal block with at least ten terminals.



- (e) Visor. The conventional signal section shall be furnished with a tunnel type visor, and the optically programmed signal section shall be furnished with a cutaway type visor. The visor shall be a minimum of 1.2 mm (0.05 in.) in thickness. The visor for a 200 mm (8 in.) signal section shall be a minimum of 175 mm (7 in.) in length and the visor for a 300 mm (12 in.) signal section shall be a minimum of 225 mm (9 in.) in length.
- (f) Mounting Bracket. The mounting bracket shall be made of steel or aluminum. Signal heads with more than one signal face shall be furnished with terminal compartments. Each terminal compartment shall contain a terminal block with at least 16 terminals.
- (g) Finish. The aluminum signal head shall be painted according to Section 851 except the primer shall be applied to all areas. For polycarbonate signal heads, the colors specified in Section 851 shall be an integral part of the material composition.

**1078.02 Pedestrian Signal Head.** The pedestrian signal head shall be according to the ITE Standards.

- (a) Housing and Door. The housing and door of each section shall be according to Article 1078.01(b).
- (b) Optical Unit. Each signal section shall have an optical unit according to Article 1078.01(c), except the lamp for a 300 mm (12 in.) section shall be nominal 90 W, 1040 lumens with a minimum average rated life of 8,000 hours (0.91 year) and the lamp for a 225 mm (9 in.) section shall be nominal 54 W, 530 lumens with a minimum average rated life of 8,000 hours (0.91 year). When specified on the plans, symbolic walk (walking person) and don't walk (upraised palm) indications shall be used.
- (c) Terminal Block. Each pedestrian signal face shall contain a terminal block with at least eight terminals.
- (d) Visor. The visor for each signal shall be either the tunnel visor or the low profile visor. The tunnel visor shall be according to Article 1078.01(e).

The low profile visor shall be no deeper than 50 mm (2 in.) and shall consist of louvers to provide, shade from the direct sun rays and a cutoff angle restricting the unintended viewing of the signal indication. The low profile visor shall be impregnated black polycarbonate, eliminating the deterioration of the color and texture of the visor from the exposure to the ultraviolet sun rays.

- (e) Mounting Bracket. The mounting bracket shall be according to Article 1078.01(f), except no terminal compartment will be required.
- (f) Finish. The aluminum pedestrian signal heads shall be according to Section 851 except the primer shall be applied to all areas. For polycarbonate pedestrian signal heads, the colors specified in Section 851 shall be an integral part of the material composition.

**1078.03 Traffic Signal Backplate.** The traffic signal backplate shall be made of sheet aluminum, sheet ABS plastic, or ABS plastic (vacuum formed). The sheet aluminum shall have a nominal thickness of 1.3 mm (0.05 in.) and shall be according to ASTM B 209, Alloy 3003-H14 or better. The sheet ABS plastic shall have a nominal thickness of 2.5 mm (0.1 in.) and shall have a minimum tensile strength of 30,000 kPa (4,300 psi) at 23 °C (73 °F). The vacuum formed ABS plastic backplate shall have a nominal thickness of 3 mm (1/8 in.), a nominal 12 mm (1/2 in.) deep back flange on all inside and outside edges, and a minimum tensile strength of 30,000 kPa (4,300 psi) at 23 °C (73 °F).

The backplates shall be composed of one piece. The backplate shall be designed to be attached to a signal face without interfering with the opening and closing of the traffic signal door. It shall be rectangular in shape with round corners and shall be of such dimensions as to give an exposed margin of 125 mm (5 in.) on each side. If the signal face has both 200 mm (8 in.) and 300 mm (12 in.) sections, the width shall be measured from the outside of the housing of the 300 mm (12 in.) section.

When specified the surface of the backplate shall provide openings (louvers) to allow wind to penetrate and reduce wind loading. The louver openings shall cover a minimum of 20 percent of the surface area of the backplate.

The aluminum backplates shall be shop painted with one coat of primer and two coats of dull (matte) black enamel. The painting shall be according to Section 851. For the plastic backplates, the black color shall be an integral part of the material composition and shall not deteriorate under the exposure to ultraviolet sun rays.

**1078.04 Directional Louver.** The directional louver shall be made of aluminum alloy and shall have a minimum of five vanes. The directional louver shall be shop painted with one coat of primer and two coats of dull (matte) black enamel. The painting and materials shall be according to Section 851.

## SECTION 1079. DETECTOR LOOP

**1079.01 Inductive Loop Detector.** The inductive loop detector shall be according to the NEMA Standards for Traffic Control Systems, TS 1 and the following:

(a) Functions.

The inductive loop detector shall have a minimum of seven levels of sensitivity control and shall be of sufficient sensitivity to detect the smallest licensable motor vehicle, including motorbikes.

The inductive loop detector shall have a minimum of two modes of operation, presence or pulse.

The inductive loop detector shall be capable of self tuning.

The inductive loop detector shall, in a failure condition, register a continuous call to the signal controller.

Extend Call – Delay Call. The inductive loop detector shall change from delay mode to extend mode and vice versa at the end of the time set for each mode. The inductive loop detector shall have a means of visually indicating the timings of delay and extension settings are in effect.

(b) Special Feature.

System Output. In addition to supplying normal timing output, the detector shall be capable of providing a simultaneous system output for traffic volume, occupancy, and speed measuring. The system output shall be constant and not affected by delay or extension timings. This output shall allow either presence or pulse operation which may be selectable from a front panel switch. The presence and pulse outputs shall be according to NEMA. When required, this feature shall be internal to the detector.

**1079.02 Detector Loop and Sealer.**

(a) Wire. Detector loop wire is classified into three types as follows:

- (1) Type I detector loop wire and the loose encasing shall be according to IMSA 51-5.
- (2) Type II detector loop wire shall be No. 16 AWG, mineral-insulated, copper sheathed cable. The conductor shall be insulated with magnesium oxide and enclosed in a seamless copper sheath with a polyethylene jacket. A terminal subassembly kit composed of a pot, cap, sealer, and sleeves shall be supplied with the cable.
- (3) Type III detector loop wire shall be No. 14 or 16 AWG, Type THWN, THHN, or XHHW, with stranded copper conductor.

(b) Preformed Detector Loop. The preformed detector loop shall be either of the following:

- (1) Rigid Plastic Conduit. The rigid plastic conduit shall be 16 mm (5/8 in.) outer diameter schedule 80 PVC or polypropylene conduit. All bends shall be a 150 mm (6 in.) radius minimum and shall be integral to the conduit.
- (2) Heavy Duty Reinforced Rubber Hose Conduit. The heavy duty reinforced rubber hose conduit shall be Class A oil resistant, hydraulic-type rubber hose reinforced with synthetic cord. It shall have an inner diameter of 9.5 mm (3/8 in.) and an internal pressure rating of 1,720 kPa (250 psi). The loop shall be preformed with a sealed tee connection, and shall be part of one continuous piece with initial lead-in connection wires. No joints or splices shall be made in the loop or wire except for their connection to the lead-in wires located outside of the pavement.

(b) Sealer. The Sealer for Type I detector loop shall be one of the following:

- (1) Polyurethane or Two-Component Polyurethane Modified Asphalt. The material shall be cured to be rubber like, and suitable for sealing detector loops in both bituminous and concrete pavements. The cured material shall be highly resistant to oil, gasoline, salts, acids, and alkalis.
- (2) Two Component Epoxy or Two Component Polyester Resin. The material shall be cured to be flexible, and suitable for sealing detector loops in both bituminous and concrete pavements. The cured material shall be highly resistant to oil, gasoline, salts, acids, and alkalis.

The above material shall have the following properties:

Pot life at 25 °C (77 °F)	13 minutes minimum
Cure Time	4 hours maximum
Shore D Hardness	28 minimum

OTHER ITEMS

SECTION 1080. FABRIC MATERIALS

**1080.01 Fabric Envelope for Pipe Underdrains.** The fabric envelope for encasing pipe underdrains may be either a knitted, woven, or nonwoven fabric.

(a) Fabric Materials

- (1) Knitted Fabric. Knitted fabric envelope shall be an approved continuous one piece knitted polyester material that fits over the pipe underdrain like a sleeve. It shall be knitted of continuous 150 denier polyester yarn and shall be free from any chemical treatment or coating that might significantly reduce porosity and permeability.
- (2) Woven or Nonwoven Fabric. The filaments for woven or nonwoven fabric shall be polypropylene, polyester, or polyethylene. The filaments must be dimensionally stable (i.e., filaments must maintain their relative position with respect to each other) and resistant to delamination. The filaments must be free from any chemical treatment or coating that might significantly reduce porosity and permeability. Nonwoven fabric shall be needle punched.

- (3) **Physical Properties.** The physical properties for both knitted and woven or nonwoven fabric shall conform to the following:

PHYSICAL PROPERTIES			
	Knitted		Woven or Nonwoven
Min. Weight (g/sq m)	120 applied 160 relaxed	ASTM D 3887 ASTM D 3887	120 ASTM D 3776
Min. Wet Grab Tensile Strength (N)	225	ASTM D 4632	450 <sup>1/</sup> ASTM D 4632
Grab Elongation @ Break (%)		--	20 min. <sup>1/</sup> ASTM D 4632
Equivalent Opening Size (EOS No.)	600 µm min	<sup>2/</sup> Corps of Engrs. CW-02215	600 µm nonwoven <sup>2/</sup> 300 µm min. woven <sup>2/</sup>
Burst Strength (kPa)	690 min. <sup>2/</sup>	ASTM D 3887	- -

PHYSICAL PROPERTIES (ENGLISH)			
	Knitted		Woven or Nonwoven
Min. Weight (oz./sq yd)	3.5 applied 4.8 relaxed	ASTM D 3887 ASTM D 3887	3.5 ASTM D 3776
Min. Wet Grab Tensile Strength (lb)	50	ASTM D 4632	100 <sup>1/</sup> ASTM D 4632
Grab Elongation @ Break (%)		--	20 min. <sup>1/</sup> ASTM D 4632
Equivalent Opening Size (EOS No.)	30 min. <sup>2/</sup>	Corps of Engrs. CW-02215	30 min. nonwoven <sup>2/</sup> 50 min. woven <sup>2/</sup>
Burst Strength (PSI)	100 min. <sup>2/</sup>	ASTM D 3887	- -

<sup>1/</sup> For woven fabric, test results shall be referenced to orientation with warp or fill, whichever the case may be.

<sup>2/</sup> Manufacturer's certification to meet test requirements.

- (b) **Handling and Storage.** The knitted fabric envelope shall be applied to the pipe underdrain in the shop so as to maintain a uniform applied weight. Woven and nonwoven fabric or underdrains with knitted fabric envelope shall be delivered to the job site in such manner as to facilitate handling and incorporation into the work without damage. Fabric envelope materials shall be stored in UV-resistant bags until just prior to installation. In no case shall the fabric be stored or exposed to direct sunlight that might significantly diminish its strength or toughness. Torn or punctured fabric envelope shall not be used.

**1080.02 Geotextile Fabric.** Fabric for Ground Stabilization and Silt Filter Fence shall consist of woven or nonwoven filaments of polypropylene, polyester, or polyethylene. Nonwoven fabric may be needle punched, heat-bonded, resin-bonded, or combination thereof. The filaments in the Silt Filter Fence Fabric must be dimensionally stable (i.e., to each other), resistant to delamination, and must be free

from any chemical treatment or coating that might significantly reduce porosity and permeability. Both fabrics shall be resistant to ultraviolet radiation. The fabrics shall comply with the following physical properties.

Physical Properties	Ground Stabilization	Silt Filter Fence Fabric
Grab tensile strength (N) - ASTM D 4632	900 (min.) 1/	900 (min.) 1/
Grab elongation @ break (%) - ASTM D 4632	12 (min.) 1/	12 (min.) 1/
Burst strength (kPa) - ASTM D 751	1720 (min.) 2/	1720 (min.) 2/
Trapezoidal tear strength (N) ASTM D 4533	335 2/	-
Width (m)	-	1 (min.)
Weight (g/sq m) – ASTM D 3776	135 (min.)	135 (min.)
Equivalent opening size	-	600 µm (min.) (nonwoven) 2/
(EOS) Sieve No. – Corps of Engrs. CS-0221	5	300 µm (min.)(woven) 2/

Physical Properties (English)	Ground Stabilization	Silt Filter Fence Fabric
Grab tensile strength (lb) - ASTM D 4632	200 (min.) 1/	200 (min.) 1/
Grab elongation @ break (%) - ASTM D 4632	12 (min.) 1/	12 (min.) 1/
Burst strength (psi) – ASTM D 751	250 (min.) 2/	250 (min.) 2/
Trapezoidal tear strength (lb) ASTM D 4533	75 2/	-
Width (ft.)	-	3.5 (min.)
Weight (oz/sq yd.) – ASTM D 3776	4.0 (min.)	4.0 (min.)
Equivalent opening size	-	30 (min.)(nonwoven) 2/
(EOS) Sieve No. – Corps of Engrs. CS-02215		50 (min.)(woven) 2/

- 1/ For woven fabric, test results shall be referenced to orientation with warp or weave, whichever the case may be. Both woven and nonwoven fabric shall be tested wet.
- 2/ Test results may be obtained by manufacturer's certification.

**1080.03 Filter Fabric For Use With Riprap.** The filter fabric material shall consist of nonwoven filaments formed from a plastic yarn of a long chain synthetic polymer composed of at least 85 percent by weight of polyolefins, or polyesters, and 1022

shall contain stabilizers and/or inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure. After forming, the fabric shall be processed so that the filaments retain their relative positions with respect to each other. The fabric shall be free of defects or flaws which significantly affect its physical and/or filtering properties.

The filter fabric shall be formed in widths of not less than 2 m (6 ft). Sheets of fabric may be sewn together with thread of a material meeting the chemical requirements given for the plastic yarn to form fabric widths as required. The sheets of filter fabric shall be sewn together at the point of manufacturer or another approved location.

The texture of the fabric shall be such that the bedding and riprap will remain in an equilibrium state and not slip or slide. The filter fabric shall be rot proof, mildew proof, insect resistant, have a high dimensional stability when set, have good soil filtration characteristics, have a high resistance to tear propagation in all directions, and meet the following minimum conditions and ASTM Tests for the gradation of riprap specified:

METRIC UNITS	Gradation 4 & 5	Gradation 6 & 7
Weight of Fabric (g/sq m), ASTM D 3776 (Mod.)	200	270
Burst Strength (kPa), ASTM D 3786 (Note 1)	1720	2070
Trapezoidal Tear Strength (N), ASTM D 1117 (Note 2)	265	335
Grab Tensile Strength (N), ASTM D 4632 (Note 2)	700	900
Grab Tensile Elongation (%), ASTM D 4632 (Note 2)	20	20

ENGLISH UNITS	Gradation 4 & 5	Gradation 6 & 7
Weight of Fabric (oz/sq yd), ASTM D 3776 (Mod.)	6.0	8.0
Burst Strength (psi), ASTM D 3786 (Note 1)	250	300
Trapezoidal Tear Strength (lb), ASTM D 1117 (Note 2)	60	75
Grab Tensile Strength (lb), ASTM D 4632 (Note 2)	160	200
Grab Tensile Elongation (%), ASTM D 4632 (Note 2)	20	20

Note 1. Manufacturer's certification of fabric to meet requirements.

Note 2. Test sample shall be tested wet.

The vendor shall furnish certified test reports with each shipment of material attesting that the fabric meets the above requirements.

A sample of 4.0 sq m (5 sq yd) of the fabric shall be furnished from each shipment for verification testing.

The fabric shall meet the requirements noted in the following and provide an AOS (apparent opening size) determined by the Engineer after an on site investigation of the soil to be protected, based on the following criteria:

## (a) Piping Resistance. (soil retention) (Note 1)

- (1) Soil with 50 percent or less particles by mass (weight) passing U.S. 75  $\mu\text{m}$  (No. 200) Sieve. AOS less than 0.6 mm [greater than 300  $\mu\text{m}$  (No. 30) Sieve] TF25 Method 6.
- (2) Soil with more than 50 percent particles by mass (weight) passing U.S. 75  $\mu\text{m}$  (No. 200) Sieve. AOS less than 0.3 mm [greater than 300  $\mu\text{m}$  (No. 50) Sieve] TF25 Method 6.

## (b) Permeability. (cm/sec)(Note 1). K of fabric greater than 10K of soil - ASTM D 4491.

Note 1. Certification from the manufacturer of fabric is required stating that the product meets the piping resistance and permeability requirements.

**1080.04 Fabric Formed Concrete Revetment Mats.** Fabric forming material shall consist of specially woven, double layer, open selvage fabric joined in mat configuration. The fabric shall consist of uncoated synthetic yarns with sufficient grab tensile strength and porosity to withstand the pressure of the grout injection pump without breaking the layers of fabric. Each fabric layer shall exhibit minimum grab tensile strength of 900 N (200 lb) in both warp and fill directions when tested according to ASTM D 4632, Grab Tests, Method 16, using a 100 x 200 mm (4 x 8 in.) sample, 75 mm (3 in.) gage length, clamped in a 25 mm (1 in.) wide by 50 mm (2 in.) long grip, tested at a strain rate of 300 mm/minute (12 in./min) in a CRE testing machine. The average of five tests in each direction shall meet the minimum value given above. The fabric shall be tested wet.

Hydrostatic uplift pressure relief shall be provided by installing 40 mm (1 1/2 in.) diameter sewn filter points woven in such a manner as to permit passage of water through the filter points spaced approximately at 200 mm (8 in.) centers for the Filter Point style mat with average thickness of 90 mm (3.5 in.), and at 2.4 m (8 ft) centers for the Uniform Cross Section style mat with average thickness of 100 mm (4 in.). All filter points shall be checked and cleaned for free passage of water through the filter points after the mat has been pumped and the cement grout has set. When uniform cross section style mat is specified, the Contractor shall have the option of substituting filter point style mat.

**1080.05 Geotechnical Fabric for French Drains.** Geotechnical fabric for french drains shall consist of woven or nonwoven filaments of polypropylene, polyester, or polyethylene. Nonwoven fabric may be needle punched, heat-bonded, resin-bonded or combinations thereof. The filaments must be dimensionally stable (i.e., filaments must maintain their relative position with respect to each other) and resistant to delamination. The filaments must be free from any chemical treatment or coating that might significantly reduce porosity and permeability.

Physical Properties. The fabric shall comply with the following physical properties:



Weight g/sq m (oz/sq yd)	120 (3.5) min.	ASTM D 3776
Grab tensile strength N (lb)	450 <sup>1/</sup> (100) min. <sup>1/</sup>	ASTM D 4632
Grab elongation @ break (%)	20 min. <sup>1/</sup>	ASTM D 4632
Equivalent opening size (EOS NO.)		CW-02215-77 Corps of Engineers
Nonwoven	600 µm (30) min. <sup>2/</sup>	
Woven	300 µm (50) min. <sup>2/</sup>	

1/ For woven fabric, test results shall be referenced to orientation with warp or fill, whichever the case may be. Both woven and nonwoven fabrics shall be tested wet.

2/ Manufacturer's certification of fabric to meet requirements.

## SECTION 1081. MATERIALS FOR PLANTING

**1081.01 Trees, Shrubs, Vines, and Seedlings.** Trees, shrubs, vines and seedlings shall conform to the current standards adopted by the American Association of Nurserymen.

### (a) Quality of Plant Material.

- (1) Plants shall be first class nursery grown representatives of their normal species and varieties. They shall have average or normal well developed branches, together with vigorous root systems. Plants shall be free from insects, diseases, sun scald, knots, stubs, or other objectionable disfigurements. Thin, weak plants will not be accepted.
- (2) Trees shall be free of branches (undertrimmed) no higher from the ground line than 1/2 the total height of the tree; shall have single leaders, be well branched, and with reasonably straight stems. This requirement shall cover general species, but some varieties, which have other characteristics of growth, will be accepted.
- (3) Plants shall be true to their name as specified. Substitution of plant material of equal quality, type, and size to that specified may be approved by the Engineer at no change in unit price if acceptable material of the variety specified is not available. Permission shall be given only after a written request and proposal for substitution is received from the Contractor 30 days prior to the proposed planting date.
- (4) Wherever the word "specimen" is used, it shall denote trees which are symmetrical, exceptionally heavy, and full branched. When more than one is required, all shall be uniform in size and shape.

- (5) The southernmost limits for the source of plant material shall be one sub-zone south of the site of the work. Plant Hardiness Zones shall be as designated in the current Miscellaneous Publication No. 814, Agricultural Research Service USDA. All Illinois counties located in sub-zone 5a shall be considered part of sub-zone 5b. All counties located in sub-zone 7a shall be considered part of sub-zone 6b.

(b) Measurement for Size.

- (1) Root System. The root system of all plants shall be sufficient to ensure plant growth.
  - a. Bareroot Trees. All bareroot trees shall have a heavy fibrous root system that has been developed by proper cultural treatment, transplanting, and root pruning.
  - b. Bareroot Shrubs. All bareroot shrubs shall have a well-branched fibrous root system.
- (2) Container Grown Plants. Container grown plants shall be well rooted and established in the container in which they are growing. They shall have grown in the container for a sufficient length of time for the root system to hold the earth when taken from the container, but not long enough to become pot bound.
- (3) Balled and Burlapped Plants. Plants marked "B&B" are to be balled and burlapped, and shall be dug with a sufficient quantity of earth taken equally on all sides and bottoms of the plants to include the necessary roots to ensure growth.

(c) Inspection of Plant Material.

- (1) Inspection of plant material will be made at the nursery by the Engineer, or a duly authorized representative, whenever such an examination is deemed practical, and must be in the field (or in storage houses) of the nursery supplying the material. The Department reserves the right to place identification seals on any or all plants selected.
- (2) Approval of material on such an examination shall not be as construed as an acceptance of it. Final acceptance will not be made until the plant material is in a healthy, growing condition as provided in Article 253.14.
- (3) With respect to inspection for plant diseases and insect infestation, an inspection certificate shall accompany each shipment and on arrival the certificate shall be filed with the Engineer.

(d) Shipment.

- (1) Each species or variety shall be handled and packed in the manner approved for that plant, having regard for the soil and climatic conditions at the time and place of digging and of delivery, and to the time that will be consumed while in transit or delivery. All precautions that are

customary in good trade practice shall be taken to ensure the arrival of the plants in good condition.

- (2) Plants shall be packed or covered in such a manner as to ensure adequate protection against damage while in transit. The roots of bare root plants shall be carefully protected with wet straw or other suitable material to ensure the arrival of the plants at destination with the roots in a moist condition.
- (3) When shipment is made by an enclosed vehicle, the vehicle shall be adequately ventilated to prevent any "heating" in transit.
- (4) Unless requested by the Engineer, only a representative amount of shrubs, seedlings or liners need to be tagged. All other stock furnished must be legibly tagged with the name or the corresponding key designation as indicated on the plans.

#### **1081.02 Perennial Plants.**

- (a) Bulbs and Tubers. Bulbs and tubers shall meet the current American Standards for Nursery Stock. The Contractor shall furnish the Engineer a shipping ticket or label documenting that the variety, color, and size of the bulbs or tubers supplied are as specified.
- (b) Herbaceous Plants. Herbaceous plants shall meet the current American Standards for Nursery Stock. If a pot size is not specified, plants shall be supplied potted or bare root at a minimum size of one year old plant of the specified species, except that bare root plants will be acceptable only for the spring planting season. Flats or bundles of plants shall be clearly labeled by variety, and the Contractor shall furnish the Engineer a shipping ticket or label documenting that the plants supplied are as specified.

**1081.03 Sod.** Each piece of sod shall be well covered with turf grass, shall be free from noxious weeds and other objectionable plants, and shall not contain substances injurious to growth. The grass shall be cut to a length of not less than 40 mm (1 1/2 in.) nor more than 100 mm (4 in.) before the sod is cut. The sod shall be cut in rectangular pieces with its shortest side not less than 300 mm (12 in.). The sod shall not be cut less than 25 mm (1 in.) thick. This thickness measurement does not include grass.

With respect to inspection for plant diseases and insect infestation, an inspection certificate shall accompany each shipment and on arrival shall be filed with the Engineer.

- (a) Native Sod. The sod used shall be approved grass that is native to the locality of work. It shall be either nursery grown or field grown and be well rooted and approved by the Engineer prior to being cut and again before it is laid. Sod that has been grown on soil high in organic matter such as peat will not be acceptable. The consistency of adherent soil shall be such that it will not break, crumble or tear during handling and placing of the sod.
- (b) Salt Tolerant Sod.

<u>Variety</u>	<u>Percent by Weight</u>
Buffalo Grass Buchloe dactyloides	30%
Amigo fineleaf tall fescue	20%
Dawson Red fescue	15%
Scaldis hard fescue	15%
Rugby Kentucky Bluegrass	5%
Fults Pucinnellia Distans	15%

**1081.04 Seeds.**

- (a) Sampling and Testing. Each lot of seed, except Prairie Forbs, furnished shall be tested by a State Agriculture Department (including other States) or by land grant college or university agricultural sections or by a Registered Seed Technologist.

Acceptance of seeds furnished will be based on receipt and approval of a certification covering tests from each lot of seed. Certification shall consist of test reports showing the required test results of lots corresponding to the shipment and signed by the responsible personnel of the testing agency. A Registered Seed Technologist shall verify his/her signature with his/her Society of Commercial Technologists' seal.

Seeds may be sampled at destination on a random basis and tested for comparison with certification and compliance with these requirements. If deviations are found, the results will be reviewed to determine if the material is acceptable for use. Major deviations may result in a requirement that each lot of material from the source in question be sampled, tested, and approved by the State Agriculture Department before further use.

- (b) Packing and Storage. Seeds shall be packed for delivery in suitable bags according to standard commercial practice. Each bag shall be tagged or labeled. If it is necessary to store the seeds after their arrival on the work site, they shall be stored in an approved weatherproof building in such a manner as to protect the seeds from deterioration and to permit easy access for inspection. The Engineer's approval of the storage building and the method of storage shall not relieve the Contractor of his/her responsibility for the quality and fitness of the seeds at the time of their use.
- (c) General Requirements.
  - (1) Variety and Origin. All seeds shall be guaranteed by the vendor to be true to name and variety. Whenever a particular origin is specified, all seeds furnished shall be guaranteed to be from that origin.

- (2) Mixtures. Seed mixtures shall be proportioned by weight. Mixing of the individual varieties of seed to form such mixtures shall be performed under the supervision of the Engineer.
- (3) Noxious Weed Seeds. No seeds shall be sown until they have been tested for purity and until such tests indicate that the seeds do not contain any seeds of the noxious weeds classed as "Primary Noxious Weed Seed" and not more than the maximum number per gram (ounce) sample, specified in Table II, Noxious Weeds classed as "Secondary Noxious Weed Seed".
- (4) Hard Seeds. In determining the viable germination percent of legumes, the percent hard seed is to be added to the percent test germination; however, the percent hard seed added shall not exceed the maximum specified in Table II when planted in the fall season.
- (5) Seed Purity. Seeds having a purity that is below the purity specified in Table II will be rejected. Seeds having a total inert matter and weed seed content greater than 20 percent of the sample in cases of bluegrass, redtop, orchard grass, brome grass, and creeping red fescue, and greater than three percent in all other agricultural seeds listed in Table II, will be rejected. Any sample containing more than five percent by mass (weight) of seed of other cultivated plants will be rejected. Seeds that fail to meet the requirements of Table II, "Maximum Weed Seed Percent" and "Remarks", will be rejected.
- (6) Pure, Live Seed. Pure, live seed shall be defined as the sproutable seed of a specified variety and calculated as the product of the viable germination times the purity. The seed kg/ha (weights/acre) listed in Table I of Article 250.07, "Seed Mixtures", are designed to yield specific amounts of pure, live seed/hectare (acre) based on the pure, live seed percent values listed in Table II of this Article. Seed which has actual pure, live seed yield according to tests less than the intended yield will have the specified quantity adjusted to meet the intended pure, live seed yield. The adjusted weight to be sown will be calculated as follows:

$$\text{Adjusted kg/hectare (lb/acre)} = \frac{\text{Intended pure live seed per hectare (acre)} \times 100}{\text{Actual pure live seed percent}}$$

Where:

$$\begin{array}{l} \text{Intended pure} \\ \text{Live seed per hectare (acre)} \\ \text{(Table I, Article 250.07)} \end{array} = \begin{array}{l} \text{Specific kg/hectare (lb/acre)} \\ \times \text{Pure live seed percent} \\ \text{(Table II, Article 1081.04)} \end{array}$$

$$\text{Actual pure live seed percent} = \frac{\text{Actual germination percent} \times \text{actual purity percent}}{100}$$

Seeds which meet the noxious weed seed and purity requirements may be sown prior to the completion of the germination test provided an additional amount of seed, specified by the Engineer, is used without additional compensation.

TABLE II						
Variety of Seeds	Hard Seed Percent Maximum	Purity Percent Minimum	Pure, Live Seed Percent Minimum	Weed Percent Maximum	Secondary Noxious Weeds No. per kg (oz) Max. Permitted*	Remarks
Alfalfa	20	92	89	0.50	211 (6)	1/
Brome Grass	-	75	68	2.00	175 (5)	-
Clover, Alsike	15	92	87	0.30	211 (6)	2/
Clover, Crimson	15	92	83	0.50	211 (6)	-
Clover, Ladino	15	92	89	0.30	211 (6)	-
Clover, Red	20	92	89	0.30	211 (6)	-
Clover, White Dutch	30	92	88	0.30	211 (6)	3/
Dawson Red Fescue	0	97	85	0.10	105 (3)	-
Fescue, Alta or Ky. 31	-	92	88	1.00	211 (6)	-
Fescue, Creeping Red	-	75	82	1.00	211 (6)	-
Fults Salt Grass	0	98	85	0.10	70 (2)	-
Kentucky Bluegrass	-	75	72	0.50	247 (7)	5/
Lespedeza, Korean	20	92	84	0.50	211 (6)	3/
Oats	-	92	88	0.50	70 (2)	4/
Orchard Grass	-	75	70	1.50	175 (5)	4/
Redtop	-	75	78	1.80	175 (5)	4/
Ryegrass, Perennial, Annual	-	92	88	0.50	175 (5)	4/
Rye, Grain, Winter	-	92	83	0.50	70 (2)	4/
Scalds Hard Fescue	0	97	85	0.10	105 (3)	-
Timothy	-	92	84	0.50	175 (5)	4/
Vetch, Crown	30	92	67	1.00	211 (6)	3/ & 6/
Vetch, Spring	30	92	88	1.00	70 (2)	4/
Vetch, Winter	15	92	83	1.00	105 (3)	4/
Wheat, hard Red Winter	-	92	89	0.50	70 (2)	4/

- 1/ Shall be grown in Kansas or farther north; shall be free from any mixture with southern or foreign seeds, blends or adulterations with screenings, frosted or damaged seeds; and shall not contain more than 0.2 percent bur or sweet clover mixture.
- 2/ Shall be free from blends or adulterations with screenings, blasted, shriveled or immature seeds.
- 3/ Shall be hulled and free from blends or adulterations with blasted, shriveled, or immature seeds.
- 4 Shall be recleaned.
- 5/ Shall not contain more than five percent adulteration with Canada Blue Grass, Merion Blue Grass, or other hybrids or varieties of blue grass.
- 6/ Shall be scarified.

\* No primary Noxious Weeds are permitted.

- (7) Native Grass Mixture. The seed quantities indicated per hectare (acre) for Prairie Grass Seed in Class 4 Seeding and the Prairie Grass Seeds in Class 3 in Article 250.07 shall be the amounts of pure, live seed per hectare (acre) for each species listed. Seed which has actual pure, live seed yield according to tests less than the intended yield, will have the specified quantity adjusted to meet the intended pure, live seed yields.

Thirty days prior to the time of seeding, the Contractor shall provide for the approval of the Engineer, a written description for the Prairie Forbs seed mix showing the percentage by mass (weight) of each of the kinds of seed. This description shall also include the following:

- a. Name and location of the seed supplier.
  - b. Origin and date of harvest of each of the various kinds of seed.
  - c. A statement of the purity and germination of the seeds.
  - d. The estimated number of seeds/ kg (lb) of each of the kinds of seed to be furnished.
- (8) Temporary Erosion Control Seeding. Seeds shall consist of Oats from March 1st to July 31st and Winter wheat from August 1st to November 15th. Seed shall be delivered to the job site in unopened, labeled bags. A certification from the supplier stating the weight and contents of the bag shall be printed on or attached to each bag along with a certification stating that the seed meets the requirements of Article 1081.04(c).

#### **1081.05 Topsoil and Compost.**

- (a) Topsoil. Topsoil shall be loamy soil from the A horizon of soil profiles of local soils. It must have an organic content between one and ten percent. It shall be relatively free from large roots, sticks, weeds, brush, or stones larger than 25 mm (1 in.) in diameter, or other litter and waste products. At least 90 percent must pass the 2.00 mm (No. 10) sieve and the pH must be between 5.0 and 8.0.

Topsoil shall be capable of supporting and germinating vegetation.

- (b) Compost. Compost shall be thoroughly decomposed organic waste produced at an IEPA registered composting facility. All compost shall be approved by the Engineer. This compost shall have no glass or metal shards present. Any plastic or other man made material shall be no larger than 6 mm (1/4 in.) and sieved out to be less than one percent of the total dry weight. A copy of the compost test results complying with IEPA standards for General Use Compost and certification of IEPA registration must be provided to the Engineer with each shipment of compost.

Compost shall be capable of supporting and germinating vegetation.

**1081.06 Mulch.** Mulch material for seeding and planting shall be non-toxic to vegetation and to the germination of seed and shall be approved by the Engineer.

(a) Seeding. Mulch material for seeding shall be as follows:

- (1) Straw. Straw shall be stalks of wheat, rye, oats or other approved straw, and shall be air dried.
- (2) Hydraulic Mulch. Hydraulic mulch shall be virgin or recycled wood cellulose or paper fibers containing no growth or germination inhibiting factors. Hydraulic mulch shall disperse evenly and rapidly and remain in slurry when agitated with water. The slurry shall be green in color to allow visual metering of its application and, when sprayed uniformly on the surface applied to, shall form an absorbent cover allowing percolation of water to the underlying surface. Hydraulic mulch shall be packaged in moisture resistant packages or bags with the net quantity of the packaged material plainly shown on each such package. The wood cellulose or paper fibers shall not be water soluble and shall comply with the following properties when tested according to the procedures outline in Federal Specification O-P-166. The recycled wood cellulose or paper fibers shall be relatively free of glossy papers.

Moisture content, as received basis, Percent by mass (weight), maximum	15
Organic matter, wood, fiber oven-dried basis, Percent by mass (weight), minimum	95
PH	4.3-8.5
Water holding capacity, oven dried basis, Percent by mass (weight), minimum	400

- (3) Chemical Mulch Binder. Chemical mulch binder shall be a commercially available product specifically recommended by the manufacturer for use as a mulch stabilizer.

The mulch binder shall be nonstaining and nontoxic to vegetation and the environment. It shall disperse evenly and rapidly and remain in suspension when agitated in water. The mulch binder and water suspension or slurry shall be green in color to allow visual metering of its application.

Prior to use of the mulch binder, the Contractor shall submit a notarized certification by the manufacturer stating that it meets these requirements. Chemical mulch binder shall be packaged, stored, and shipped according to the manufacturer's recommendations with the net quantity plainly shown on each package or container.

- (b) Planting. The mulch material for planting shall consist of shredded tree bark, wood chips, or other approved organic mulch as specified in the plans. The mulch must be approved by the Engineer prior to placement.



**1081.07 Agricultural Ground Limestone.** Agricultural Ground Limestone shall contain particles ground sufficiently fine so that essentially all material pass a 4.75 mm (No. 4) sieve and is graded relatively uniform through the 2.36 mm, 600 µm and 250 µm (Nos. 8, 30 and 60) sieves. Approved sources of Agricultural Ground Limestone shall be tested by the Department of Agriculture and rated with a source correction factor.

**1081.08 Fertilizer.** Fertilizer shall be ready-mixed material of an analysis specified on the plans and as directed by the Engineer. In cases where a single nutrient is requested, the analysis shall be optional, provided that it carries sufficient filler to ensure adequate distribution of the nutrient.

- (a) The following information shall be shown on the fertilizer bag or package, or on an attached tag:

- (1) Name and address of manufacturer
- (2) Name, brand or trademark
- (3) Number of net kilograms (pounds) of ready-mixed material in the package
- (4) Chemical composition or analysis
- (5) Guarantee of analysis

If a brand or grade of fertilizer is delivered in the bulk, a written statement having the above listed information must accompany each load.

- (b) Custom mixed fertilizers shall have a written statement containing the following information with each load:

- (1) Weight of each commercial fertilizer used in the custom mix.
- (2) The guaranteed analysis of each commercial fertilizer used in the custom mix.
- (3) Total weight of fertilizer delivered in each load.
- (4) The manufacturer of each of the commercial fertilizers used in the custom mix.
- (5) Guaranteed analysis of each load to be stated as follows:
  - a. Percent of total Nitrogen (N)
  - b. Percent of total available Phosphoric ( $P_2O_5$ )
  - c. Percent of total Soluble Potash ( $K_2O$ )

- (6) Name and address of the person selling the fertilizer.

**1081.09 Peat Moss.**

- (a) Peat moss shall be partially decomposed fibrous or cellular stems and leaves of any of several species of sphagnum mosses, and shall conform to the following requirements:
- (1) Texture and Composition. Its texture may vary from porous fibrous and spongy fibrous, and it shall be either crumbly or compact, but fairly elastic and substantially homogeneous. It shall be free from decomposed colloidal residue, excessive woody materials (roots and stems), and shall be essentially dark brown in color. Shredded particles shall not exceed 6 mm (1/4 in.) in size.
  - (2) Acidity. The pH value shall be not less than 3.2 and not greater than 5.5, at approximately 25 °C.
  - (3) Ash. The ash content, based on the oven dry weight of the material, shall be not more than five percent.
  - (4) Water Holding Capacity. The water holding capacity shall not be less than 400 percent, by weight, on an oven dry basis.
- (b) Sampling. A test sample weighing at least one pound shall be taken from each 45 metric ton (50 ton) lot or fraction thereof. Such samples shall be taken 152 mm (6 in.) below the surface of one or more bales, thoroughly mixed, and placed in a clean, dry, air tight, metal container or in a strong plastic bag, sealed and forwarded to the testing laboratory.
- (c) Testing. The samples will be tested in accordance with the requirements of Article 4.5 of the Federal Specifications for Peat Moss; Peat, Humus; and Peat, Reed-Sedge, Q-P-166e.
- (d) Packing. The air dried peat moss shall be packed in bales of the type, size, and kind commonly used. Damaged bales will not be accepted.

The peat moss shall be packed in the bales at a compression ratio of at least 2 to 1. Each bale shall be clearly marked with the type of peat moss, the brand name, the country of origin, the cubic meter (cubic feet) compressed size, the compression ratio used, and the approximate mass (weight) of the bale. Each shipment shall be accompanied by a certificate stating that the peat moss meets the specified requirements.

**1081.10 Special Erosion Control Materials.**

Erosion Control Blanket. Erosion control blankets shall be fabricated solely from materials described below, in whole, or in approved combinations of not more than two of the components described below. When two values are specified, properties of blankets composed of combinations of materials shall conform to the lower of the two values specified for the individual components. Each component shall also meet its individual physical requirements.

- (a) **Excelsior Blanket.** Excelsior blanket shall consist of a machine produced mat of wood excelsior of 80 percent 150 mm (6 in.) or longer fiber length. The wood from which the excelsior blanket is cut shall be properly cured to achieve adequately curled and barbed fibers.

The blanket shall be of consistent thickness, with the fiber evenly distributed over the entire area of the blanket. The excelsior blanket shall be covered on the top side with a 90 day biodegradable extruded plastic mesh netting having an approximate minimum opening of 16 x 16 mm (5/8 x 5/8 in.) to an approximate maximum opening of 50 x 25 mm (2 x 1 in.). The netting shall be substantially adhered to the excelsior blanket by a knitting process using biodegradable thread or by an applied degradable adhesive. The netting shall be substantially adhered to the excelsior by a knitting process using biodegradable thread. The netting shall be entwined with the excelsior blanket for maximum strength and ease of handling.

The excelsior blanket shall comply with the following:

Minimum width,  $\pm 25$  mm (1 in.)..... 600 mm (24 in.)

Minimum mass  $\pm 10$  % .....0.34 kg/sm (0.63 lb/sq yd)

Minimum length of roll, approximately ..... 45 m (150 ft)

The excelsior blanket shall be smolder resistant and shall withstand the following test:

The excelsior blanket specimen shall not flame or smolder for more than a distance of 300 mm (12 in.) from a spot where a lighted cigarette is placed on the surface of the blanket.

**Certification.** The manufacturer shall furnish a certification with each shipment of excelsior blanket stating the number of rolls furnished and that the material complies with these requirements.

- (b) **Knitted Straw Mat.** Knitted straw mat shall be a machine-assembled blanket whose primary component is clean, weed free straw from agricultural crops. The straw must be evenly distributed throughout the blanket to a loose thickness of approximately 13 mm (1/2 in.) with a permissible variation of  $\pm 3$  mm (1/8 in.). The top side of the blanket shall be covered with biodegradable plastic mesh of 10 x 10 mm (3/8 x 3/8 in.) square openings with a permissible variation of  $\pm 3$  mm (1/8 in.) and shall be substantially adhered to the straw by a knitting process using biodegradable thread. The plastic mesh shall degrade within 90 days.

The blanket shall be supplied in a protected rolled mat form of 2 m (6 1/2 ft) minimum width and the average dry mass (weight) shall not be less than 0.27 kg/sq m (0.50 lb/sq yd).

Certification. The manufacturer shall furnish a certification with each shipment, stating the number of rolls furnished and that the material complies with these requirements.

- (c) Heavy Duty Erosion Control blanket. The Heavy Duty Erosion Control Blanket shall meet the requirements of Article 1081.10 (a), except as follows:

Minimum width, ± 25 mm (1 in.) .....	1.2 m (48 in.)
Minimum weight ± 10 % .....	0.79 kg/sq m (1.45 lb/sq yd)
Minimum length of roll, approximately .....	30 m (100 ft)

Both the top and bottom side of each blanket shall be covered with heavy duty extruded plastic mesh which contains an ultraviolet inhibitor for added longevity.

- (d) Wire Staples. Staples shall be made from No. 11 gage or heavier uncoated black carbon steel wire of sufficient stiffness for soil penetration. They shall be of the "T" or "U" configuration with pointed ends, 25 to 50 mm (1 to 2 in.) wide at the top and a minimum overall length of 150 mm (6 in.) from top to bottom. The staples for Heavy Duty Erosion Control Blanket shall be as specified here except that the legs shall be 200 mm (8 in.) or longer. The staples shall be packaged in cartons.
- (e) Wood Stakes. Hardwood blanket anchors shall be approximately 180 mm (7 in.) long from neck of hook to tip of anchor. The wood shall not break during installation. The anchor shall have a 13 mm (1/2 in.) curving hook to hold the blanket in place.
- (f) Coconut Fiber. Coconut fiber shall only be used in combination with another approved material (straw fiber, wood excelsior, or synthetic fiber) as a form of temporary erosion control blanket or with synthetic fibers as the erosion control blanket portion of a flexible channel liner.

When used for flexible channel liners, the erosion control portion of the blanket shall consist of 100 percent coconut fiber with consistent thickness and fiber evenly distributed over the entire area of the blanket. Both sides of the blanket shall be covered with a polypropylene mesh having ultraviolet additives to reduce breakdown. The blanket shall have a mesh size of 10 x 10 mm (3/8 x 3/8 in.). The blanket shall be sewn together, to the synthetic fiber portion of the channel liner with polyester biodegradable or photodegradable thread.

When used in combination with straw fiber as part of an erosion control blanket, the blankets shall meet the following fiber densities:

Coconut Fiber Content	30%	0.08 kg/sq m	(0.15 lb/sq yd)
Straw Content	70%	0.19 kg/sq m	(0.36 lb/sq yd)

The blanket shall be supplied in a protected rolled mat form of 2 m (6 1/2 ft) width and the average dry mass (weight) shall not be less than 0.27 kg/sq m (0.50 lb/sq yd).

**Certification.** The manufacturer shall furnish a certification with each shipment, stating the material complies with these requirements and the number of rolls furnished.

- (g) **Temporary Erosion Control Seeding.** Seeds shall consist of Oats from March 1<sup>st</sup> to July 31<sup>st</sup> and Winter wheat from August 1<sup>st</sup> to November 15<sup>th</sup>. Seed shall be delivered to the job site in unopened, labeled bags. A certification from the supplier stating the weight and contents of the bag shall be printed on or attached to each bag along with a certification stating that the seed meets the requirements of Article 1081.04(c).

**1081.11 Precast Block Revetment Mat. Materials.** Precast block revetment mats are an erosion control system consisting of three directional interlocking precast concrete blocks, 200 mm (8 in.) thick, with a woven polypropylene fabric constructed on a prepared slope. The general shape of the interlocking units shall be as shown on the plans. The interlocks shall be beveled to enable the system to conform to changing land contours and grades. The concrete components shall be precast units constructed in accordance with the applicable portions of Articles of the Standard Specifications, except that the concrete compressive strength shall not be less than 20,600 kPa (3,000 psi) in 28 days. Cement content shall not be less than 360 kg/cu m (6.00 hundredweight/cu yd). In addition to the coarse aggregate gradations allowed under Articles 1004.02 and 1020.04, gradation CA 16 will be permitted. The concrete blocks may be fabricated in the field or at the factory.

**1081.12 Articulated Block Mat. Materials.** The articulated block mat will consist of open concrete blocks interconnected by flexible cables which provide articulation and flexibility between adjacent blocks. The concrete blocks will have a minimum of 20 percent open area to allow vegetation to grow and eventually cover the concrete. The articulated block mat shall handle a flow of 1.2 to 1.4 m/s (4.0 to 4.5 fps).

**1081.13 Bracing.**

- (a) **Steel Posts.** Steel posts for bracing shall be of a type normally used for agricultural fencing; have a steel anchor plate welded or riveted to each post approximately 450 mm (18 in.) from the bottom of the post, be 1.8 m (6 ft) minimum in length, and shall weigh not less than 1.5 kg/m (1 lb/ft). The post shall be finished with a suitable paint of acceptable color or galvanizing unless specified for use as selective mowing stakes. When specified for selective mowing stakes, the steel posts shall be finished in an acceptable color of green paint. For delineating seedling plantings, the posts shall have the top 250 mm (10 in.) painted with two coats of State equipment orange paint. For delineating native grass, wildflower and ornamental herbaceous plantings, the top 250 mm (10 in.) of the posts shall be painted with two coats of white paint.

- (b) Earth Anchors. Earth anchors shall consist of a metal rod with attached spiral or helical metal anchor plate; shall conform to the following minimum requirements:

Length: 1 m (42 in.); rod diameter: 16 mm (5/8 in.); eye opening:  
25 mm (1 in.); anchor plate diameter: 100 mm (4 in.).

**1081.14 Weed Barrier Fabric.** Weed barrier fabric shall be an approved black, ultraviolet light resistant, non-woven geotextile fabric with a minimum mass (weight) of 60 g/sq m (1.75 oz/sq yd).

**1081.15 Temporary Erosion Control Materials.**

- (a) Bale Stakes. Bale Stakes shall be 1.2 m (4 ft) minimum in length and be either of sound wood 25 mm (1 in.) minimum for one dimension, metal according to Article 1006.28(d) or painted metal posts.
- (b) Fence Stakes. Fence stakes, except for silt filter fence, shall be 2.4 m (8 ft) minimum in length metal stakes according to Article 1006.28 (d) or painted metal posts. Silt filter fence stakes shall be 50 mm x 50 mm ( 2 in. x 2 in.) wood, 1.8 m (6 ft) in length.
- (c) Bales. Bales shall be either hay or straw compacted and adequately bound to an approximate size of 300 x 450 x 900 mm (12 x 18 x 36 in.).
- (d) Fence. Fence shall be a minimum of 1.2 m (4 ft) in height and may be either snow fence, flexible wooden slat fence, woven wire, or any similar material approved by the Engineer.
- (e) Aggregate. Aggregate shall include any locally available coarse aggregate, stone, broken brick, broken concrete, or riprap meeting the approval of the Engineer. The gradation required will be specified by the Engineer to control velocity and flow.
- (f) Urethane Foam/Geotextile. Urethane foam/geotextile ditch checks shall be triangular shaped having a minimum height of 200 to 250 mm (8 to 10 in.) in the center with equal sides and a 400 to 500 mm (16 to 20 in.) base. The triangular shaped inner material shall be a low density urethane foam. The outer cover shall be a woven geotextile fabric placed around the inner material and allowed to extend beyond both sides of the triangle 600 to 800 mm (2 to 3 ft.) Standard lengths of each dike shall be 2.1 m (7 ft).

(1) The geotextile shall have the following properties:

Grab tensile strength N (lb) (min.) <sup>1/</sup>	ASTM D 4632	450 (100)
Grab elongation @ brake (%) (min.) <sup>1/</sup>	ASTM D 4632	15
Burst strength kPa (psi) (min.) <sup>2/</sup>	ASTM D 751	1380 (200)
Weight g/sq m (oz./sq yds) (min.)	ASTM D 3776	135 (4.0)
Equivalent opening size (min.) <sup>2/</sup>		600 µm(30) (nonwoven)
(EOS) Sieve No. (min.) <sup>2/</sup>	Corps of Engineers CS-02215	500 µm (30) (woven)

1/ For woven fabric, test results shall be referenced to orientation with warp or weave, whichever the case may be. Both woven and nonwoven fabric shall be tested wet.

2/ Test results may be obtained by the manufacturer's certification.

(2) The urethane foam shall have the following properties:

Density kg/cu m (lb/cu ft)	ASTM D 3574	16.0 ± 1.6 (1.0 + 0.1)
Filler Content (%) by weight	ASTM D 297	0%
Tensile Strength kPa (psi) (min.)	ASTM D 3574	70 (10)
Elongation (%) (min.)	ASTM D 3574	125
Tear Resistance N/mm (lb/in.)	ASTM D 3574	0.22 (1.25)

1/ Test results may be obtained by the manufacturer's certifications.

(g) Rolled Excelsior. Rolled excelsior shall meet the manufacturer's specifications.

## SECTION 1082. PREFORMED BEARING PADS

**1082.01 Fabric Bearing Pads.** Fabric bearing pads shall consist of a fabric and rubber body made with new unvulcanized rubber and unused fabric fibers.

The rubber body shall be a natural rubber compound known as natural polyisoprene or synthetic rubber known as polychloroprene.

The average surface hardness expressed in standard rubber hardness shall be 80 ± 10 Shore A Durometer.

The ultimate breakdown limit of the pad under compressive loading shall be no less than 48,000 kPa (7000 psi) for the specified thickness without splits or deformations exceeding 10 percent of thickness after removing the load.

The pads shall be furnished to specified dimensions with all dowel holes accurately located. The thickness of fabric bearing pads shall be as shown on the plans within a tolerance of ± 1.5 mm (1/16 in.).

## SECTION 1083. ELASTOMERIC BEARINGS

**1083.01 Description.** Elastomeric Bearings shall consist of laminated elastomeric pads or assemblies of laminated elastomeric pads with externally bonded structural steel bearing plates, structural steel top bearing plate, and required stainless steel and TFE sheets, as shown on the plans and as specified.

The bond of steel components to and within the elastomeric pads shall be continuous throughout the plan area with no voids or air spaces greater than 2.5 mm (0.10 in.) within the bonding material. Bonding of TFE sheets shall be done as noted on the plans. The bearing assemblies shall be furnished as a complete unit from one

manufacturing source. Shop drawings of the bearing assemblies shall be submitted to the Engineer.

**1083.02 Elastomeric Materials.** The elastomeric materials shall be according to AASHTO M 251 (60 durometer) with the following exceptions:

- (a) Durometer hardness shall be 55 ± 5 shore points.
- (b) Bond strength shall be a minimum of 7 N/mm (40 lb/in.) and an adhesion failure of R-80 (ASTM D 429, B). The adhesion failure requirement is waived if bond strength equals or exceeds 14 N/mm (80 lb/in.).
- (c) For natural rubber the duration of test to determine ozone resistance (ASTM D 1149) shall be 100 hours.

**1083.03 TFE Material.** The TFE resin shall be 100 percent virgin material, premium grade, meeting the requirements of ASTM D 1457. The TFE sheet (polytetrafluoroethylene sheet, premium grade) shall consist of pure TFE resin, compression molded, and skived into sheets of the required thickness. The finished sheet shall conform to the following physical properties:

ASTM Standard	Physical Properties	
D 638M (D 638)	Tensile strength min, kPa (psi)	19,300 (2800)
D 638M (D 638)	Elongation, min %	200
D 792	Specific Gravity	2.15-2.20
D 2240	Hardness, Durometer D	50-65
D 621	Deformation Under Load	
	23 °C/690 kPa/24 hrs (73 °F/100 psi/24 hrs), %	2-3
	50 °C/8,300 kPa/24 hrs (122 °F/1200 psi/24 hrs), %	4-8
	23 °C/13,800 kPa/24 hrs (73 °F/2000 psi/24 hrs), %	15 max.
D 570	Water Absorption, %	0.01 max.
	Static Coef. of Friction	
	at 3450 kPa (500 psi) bearing pressure	
	on stainless steel, max	0.07
D 429, B	Adhesion to Steel	
	Peel Strength, N/mm (lb/in.)	4.4 (25)

**1083.04 Stainless Steel Sheets.** The stainless steel sheets shall be of the thickness specified and shall conform to ASTM A 240, Type 304. The sliding surface shall have a Type 2B finish or smoother as per the American Society of Metals.

**1083.05 Structural Steel.**

- (a) Structural Steel Bearing Plates. The structural steel bearing plates shall conform to the requirements of AASHTO M 270M Grade 250 (M 270, Grade 36).



- (b) **Internal Steel Laminates.** The internal steel laminates for the laminated elastomeric bearings shall be rolled mild steel sheets conforming to AISI 1015 - 1025, inclusive, ASTM A 36M (A 366) or A 569 for less than 5 mm (3/16 in.) thick sheets, or AASHTO M 270M, Grade 250 (M 270, Grade 36) or ASTM A 283M (A 283) Grade D for 5 mm (3/16 in.) and thicker sheets.
- (c) **Shear Restrictor Pin.** The shear restrictor pin, when required, shall be press fit into the bearing plate and shall be alloy steel, quenched, and tempered to a minimum yield strength 1,450,000 kPa (210,000 psi) (or RC hardness of 50 to 55).
- (d) **Threaded Stud.** The threaded stud, when required, shall conform to the requirements of AASHTO M 164M (M 164).

**1083.06 Fabrication Requirements.** Laminated elastomeric bearings shall be individually molded to the required size. Corners and edges may be rounded with a radius at the corners not exceeding 10 mm (3/8 in.) and a radius at the edges not exceeding 6 mm (1/4 in.). All edges of the embedded steel laminates, including at the laminate restraining devices and around holes and slots shall be covered with not less than 3 mm (1/8 in.) and not more than 6 mm (1/4 in.) of elastomer. No rubber flash will be permitted on the edges of TFE bearing surfaces. All burrs or raised edges along the perimeter of the TFE surface shall be removed before shipment. With the exception of the above elastomer cover tolerances, all dimension tolerances shall be according to AASHTO M 251.

Structural steel bearing plates shall be fabricated according to Article 505.04. Prior to shipment of the bearing assemblies, the exposed edges and other exposed portions of the structural steel bearing plates shall be cleaned and painted in accordance with Articles 506.03 and 506.04. Painting shall be with the zinc-silicate primer according to Article 1008.22. During the cleaning and painting, the stainless steel and TFE sheet sliding surfaces and the elastomer shall be protected from abrasion and paint.

**1083.07 Testing and Acceptance.** The rubber laminates shall be of uniform integral units, capable of being separated by mechanical means into separate, well-defined elastomeric layers. The ultimate breakdown limit of the elastomeric bearing under compressive loading shall be not less than 13,800 kPa (2000 psi).

The bearing manufacturer shall load test each completed laminated elastomeric bearing pad assembly prior to shipment. The bearings shall be loaded to 10,300 kPa (1500 psi) and under this loading shall exhibit relatively uniform bulging of the rubber layers on all sides and shall show no bond loss or edge splitting. Bearing assemblies under this loading showing nonuniform bulging from one side of the pad to the other, nonuniform bulging along any vertical face of a pad, bulging extending across the specified location of one or more of the internal steel laminates or edge splitting shall be replaced. Nonuniform bulging from one side of the pad to the other may be an indication of lateral misalignment of the internal steel laminates and would not be cause for replacement if probing shows that the edge cover of the laminates are within the specified tolerances. Nonuniform bulging along any vertical face of the pad may be an indication of vertical misalignment of the laminates and would not be cause for replacement if measurement of the bases of the nonuniform bulges show that the thickness of the elastomeric layers are within the specified  $\pm 20$  percent

tolerance. Bulging across the specified location of one or more laminates indicates missing laminates or lack of bond and pads exhibiting these characteristics shall always be replaced.

The Contractor shall furnish certified copies of the bearing manufacturer's test reports on the physical properties of the component materials for the bearings to be furnished and a certification by the bearing manufacturer that the bearings furnished have been load tested and conform to all requirements.

When directed by the Engineer, the Contractor shall furnish random samples of component materials used in the bearings for testing. In addition, when requested in writing by the Engineer, the Contractor shall furnish an additional project bearing assembly to the Department for testing. When the additional bearing assembly is requested, the Engineer retains the right to select the bearing assembly for testing at random from the project lot. The Contractor will be paid for the additional bearing assembly as specified in Article 503.22. If the bearing assembly tested is found to be unacceptable, two additional bearing assemblies will be tested. If both are acceptable, the lot will be accepted. If either of the additional two bearing assemblies are unacceptable, the lot will be rejected. The Contractor shall have a new lot produced, including one additional test bearing. No payment will be made for the original failed bearing assembly or any subsequent test assemblies.

## **SECTION 1084. TRAFFIC CONTROL DEVICES AND CONSTRUCTION SIGNS**

**1084.01 Flashing and Steady Burning Barricade Lights.** Barricade lights shall consist of a metal or plastic case, transistorized electrical circuit and head. Lights shall be maintained so as to be visible on a clear night from a distance of 900 m (3000 ft). Type B lights, when required for daylight operations, shall be maintained so as to be visible on a sunny day from a distance of 300 m (1000 ft) when viewed without the sun directly on or behind the light. All lights shall meet the requirements of the Institute of Transportation Engineers Standard for Flashing and Steady-Burn Barricade Warning Lights. Lights are classified as follows:

- Type A - Low intensity flashing
- Type B - High intensity flashing
- Type C - Steady burning

- (a) Internal Power (Batteries): The batteries shall be provided by the Contractor but shall not be installed until the light is ready to be used. The light shall be constructed so when the batteries are installed, the terminals are on top of the battery. The batteries shall be contained within the case. The battery terminals shall be either plug or spring type. All electrical connections shall be of noncorrosive material.
- (b) External Power: If external power is supplied, then all power connections shall be hermetically sealed. The method of installing these lights shall be approved by the Engineer. There shall be an isolated fuse for each light. The fuse shall be located near the pavement edge between the light and the power source and shall be installed so that if one light is damaged, causing

a short circuit, all lights will not be extinguished. In all cases, an additional emergency power supply shall be present for operation in the event of power failure. A portable generator may be used as a primary or secondary power source.

- (c) Case: The case for the battery shall be constructed of aluminum, galvanized steel, or plastic of an orange, white, or metallic color. The case shall have a vandal-proof fastener on either or on both the side and back, suitable for mounting on barricades or signs. The case shall be weatherproof.
- (d) Photoelectric Cell: All Type A and C lights shall be equipped with a switching circuit activated by a photoelectric cell. Type B lights may also be equipped with a photoelectric cell when 24-hour operation is not required in the contract.
- (e) Testing and Marking: All lights shall be tested and certified as meeting these requirements by an independent laboratory. Two copies each of the full testing report and certification shall be provided to the Engineer. The report shall specify the lens manufacturer and part number, the circuit manufacturer and part number, the bulb number, and the minimum operating voltage at which the unit meets the intensity requirements of these Specifications. Each light shall be plainly and permanently marked with the type, manufacturer's name, and model number.

1084.02 Reflective Sheeting.

- (a) Channelizing Devices. At the time of manufacturing, the reflective sheeting used on barricades and vertical panels as shown on Highway Standard 702001 shall have the following initial minimum coefficient of retroreflection expressed as average candelas per lux per sq m (candelas per foot candle per sq ft) of material. Measurements shall be conducted according to ASTM E 810.

Color	Observation Angle 0.2 Entrance Angle		Observation Angle 0.5 Entrance Angle	
	-4	+30	-4	+30
Silver/White	140.0	60.0	50.0	28.0
Orange	42.0	15.0	14.0	8.0

The reflective sheeting on drums shall conform to the requirements for barricades and vertical panels except that drums with steady-burn lights shown for lane closure tapers and runarounds on Highway Standards 701401, 701421 and 701416, and flexible delineators shown on Highway Standard 702001 shall conform to the following initial minimum coefficient of retroreflection.

Color	Observation Angle 0.2 Entrance Angle		Observation Angle 0.5 Entrance Angle	
	-4	+30	-4	+30
Silver/White	250.0	100.0	95.0	50.0
Orange	100.0	30.0	40.0	150

Sheeting color and surface shall be according to the requirements contained in Article 1084.02(b).

- (b) Construction and Maintenance Signs. All orange signs used shall be fluorescent orange in color and meet the initial minimum brightness values of the orange sheeting shown in the following table. The sign face shall consist of reflective sheeting with the appropriate screened message. The reflective sheeting shall consist of glass spherical lens elements or plastic microprismatic elements covered with a transparent plastic film having a smooth, sealed surface, except that a rectangular pattern may be embossed into the film. The sheeting shall be weather resistant.

At the time of manufacturing, the reflective sheeting shall have the following initial minimum coefficient of retroreflection at 0.2 and 0.5 divergence expressed as average candelas per lux per sq m (candelas per foot candle per sq ft) of material. Measurements shall be conducted according to ASTM E 810.

Color	Observation Angle 0.2 Entrance Angle		Observation Angle 0.5 Entrance Angle	
	-4	+30	-4	+30
Red	45.0	25.0	15.0	10.0
Silver/White	90.0	40.0	41.0	21.0
Yellow	60.0	30.0	25.0	13.0
Orange	100.0	30.0	40.0	15.0

The sheeting color shall conform to the appropriate standard color tolerance chart issued by the U.S. Department of Transportation, Federal Highway Administration.

The sheeting surface shall be smooth and flat, easily cleaned, have satisfactory wet performance, and exhibit 85° gloss-meter rating of not less than 40 when tested according to the Test for Specular Gloss, ASTM D 523. The sheeting surface shall be readily processed and compatible with

recommended transparent and opaque process inks and show no loss of the color coat with normal handling, cutting and applications.

**1084.03 Temporary Rumble Strips.** The rumble strip shall be black in color and formed of high strength polycarbonate. The strip shall be of one-piece construction with two channels on the underside for flexibility and proper adhesive bondage. The channels shall be interconnected at four or more locations to permit the bonding material to flow from one channel to the other. There shall be at least six weep holes through one or both channels to the upper surface of the strip and at least four through the leading edge of the strip to prevent air voids between the strip and the bonding material.

The rumble strip shall be capable of supporting a load of 2700 kg (6000 lb). The load capacity shall be determined by placing a strip over the open end of a 25 mm (1 in.) high vertically-positioned hollow metal cylinder having an internal diameter of 75 mm (3 in.) and a wall thickness of 6 mm (1/4 in.). The load shall be applied slowly through a 25 mm (1 in.) diameter by 25 mm (1 in.) high metal rod centered on the top flat portion of the strip. No weep holes shall be in the compression area. Breakage or significant permanent deformation of the strip shall constitute failure. Other similar designs may be used with the approval of the Engineer.

**1084.04 Construction and Maintenance Signs.** All signs used for temporary traffic control shall meet the approval of the Engineer. The sheeting shall be mounted on rigid material such as aluminum or exterior grade plywood. Signs utilizing a base of fabric, fiberboard, or other highly flexible or frangible material will not be permitted, except signs having a reflective sheeting face bonded to a durable plastic or fabric base will be permitted, (a) in work zones with posted speeds above 45 mph when workers are present to maintain the devices and (b) in all work zones having posted speeds of 45 mph or less.

**1084.05 Illuminated Sign.**

- (a) **Housing.** The housing of the illuminated sign shall be made of aluminum alloy with a minimum thickness of 1.55 mm (0.063 in.). The housing interior shall be unpainted for the fiber-optic sign and painted white for the fluorescent sign. The housing exterior shall be shop painted with one coat of primer and two coats of yellow enamel. The painting shall be according to Section 851.
- (b) **Sign Face.** The sign face shall be of Plexiglass or other plastic material with equivalent or better weathering, structural, and optical properties and shall be 3.1 mm (1/8 in.)  $\pm$  10 percent in thickness, 600 mm (24 in.) in horizontal dimension and 750 mm (30 in.) in vertical dimension. Colors of the legend and background and letters used in the legend shall conform to the MUTCD. The sign face shall be of the blank-out type, to be completely illegible when the sign is not illuminated.
- (c) **Illumination.** The fluorescent sign shall be illuminated by 8 F24-T12-CW/HO fluorescent lamps. The ballasts shall be the rapid-start type.

The fiber-optic sign shall consist of fiber-optic glass bundles arranged to define the required message. The glass bundles shall be ground smooth and optically polished at the input and output ends for maximum light transmission. The output ends of the fiber-optic glass bundles that form the sign message shall be terminated using glass lenses or glass end caps.

The fiber-optic sign shall control the lamp intensity utilizing the photo control according to Article 1078.01(c)(2)d. The lamp intensity control device shall be wired in series with the step-down transformers in the sign, on the input (120 VAC) side of the transformer. The lamp intensity control device shall be mounted in the bottom of the sign housing. Each fiber-optic sign shall have a separate lamp intensity control device.

The lamps shall have a rated minimum life of 5,000 hours.

- (d) Mounting Bracket. The mounting bracket shall be according to Article 1078.01(f), except no terminal compartment will be required.

## **SECTION 1085. GLARE SCREEN BLADES**

### **1085.01 Description.**

(a) General

- (1) The blades shall have a minimum unit mass (weight) of 0.9 kg/m (0.6 lb/ft). (The closed end shall be excluded from the total mass [weight] when determining the unit mass [weight].)

- (2) Blades shall be green in color.

- (3) Blades shall withstand a sharp bend test (180 degree bend without mandrel) at -18 °C (0 °F) without failure.

- (b) Glare Screen Blades. Glare screen blades shall be manufactured of high density polyethylene according to plans details and as follows:

- (1) Wall thickness shall be 2.5 mm (0.10 in.) minimum, except at corners where it shall be 1.5 mm (0.06 in.) minimum.

- (2) Specific gravity of the polyethylene walls shall be between 0.94 and 0.965 as determined by ASTM D 792.

- (3) Tensile strength shall be 20,700 kPa (3000 psi) minimum as determined by ASTM D 638M (D 638).

- (c) Modular Blade-Type Glare Screens. The blade-type screen modules shall be constructed of thermoplastic polyolefin (TPO) having the following physical properties:

- (1) Wall thickness shall be 2.5 mm (0.10 in.) minimum.

- (2) Specific gravity of the thermoplastic polyolefin walls shall be between 0.89 and 0.92 as determined by ASTM D 792.
- (3) Tensile strength shall be 18,000 kPa (2,610 psi) minimum as determined by ASTM D 638M (D 638).
- (d) Base Plates. Base plates shall be fabricated from 3 mm (1/8 in.) minimum steel plate according to AASHTO M 183M (M 183) and shall be galvanized according to AASHTO M 111 after fabrication.
- (e) Anchor Bolts. Anchor bolts shall consist of 10 mm (3/8 in.) expansion anchor studs with nut, flat washer and lock washer having a minimum pullout strength of 17.7 kN (4000 lb) and shall be zinc coated or stainless steel.
- (f) Self-Tapping Screws. Self-tapping screws shall be stainless steel 8 mm (5/16 in.) diameter x 16 mm (5/8 in.) Large Hex Head Type B and have an 8 x 22 mm (5/16 x 7/8 in.) outer diameter flat washer for each.

## **ELECTRICAL**

### **SECTION 1086. ELECTRIC SERVICE INSTALLATION**

#### **1086.01 Electric Service Installation- Lighting**

- (a) Overhead Electric Service.
    - (1) Service Pole and Appurtenances. The service pole shall include weatherhead guy and anchor, cable, conduit, disconnect switch, ground electrode and, if necessary, a meter socket. The pole shall be 7.5 m (25 ft) minimum Class 5 and comply with American Standards Association specifications for wood poles. It shall be Southern Yellow Pine, Western Red Cedar, or Douglas Fir treated full length with pentachlorophenol in petroleum solvent according to Edison Electric Institute Specifications, or American Wood Preservers Association Standard C4 as specified in Article 1069.01(d).
      - a. The pole shall be selected for uniformity and straightness. Sweep shall be limited to one plane and one direction only. A straight line in the plane or maximum sweep joining the surface of the pole at top and 1.8 m (6 ft) above the base end shall not be more than 50 mm (2 in.) from the surface of the pole at any point. The pole shall be machine shaved to a smooth surface.
- The pole shall be set at a depth of 1.8 m (6 ft) below grade in a hole 600 mm (24 in.) in diameter. Backfill shall consist of earth deposited in layers not more than 300 mm (12 in.) deep. Each

layer shall be thoroughly tamped by methods and tools approved by the Engineer.

b. The guy shall consist of the following:

1. 45 degree, 16 mm (5/8 in.), thimble, eye bolt
2. 6 mm (1/4 in.) thick, steel lift plate
3. Porcelain strain insulator rated not less than 2700 kg (6000 lb)
4. 200 mm (8 in.) helix, 16 mm (5/8 in.) rod thimble-eye screw anchor rated 2700 kg (6000 lb) 1.8 m (6') long.
5. Clamps, three bolt type
6. Guy wire, 2700 kg (6000 lb) tensile strength galvanized or copper clad steel.

All bolts, plates, rods, clamps and guy wires shall be galvanized in accordance with ASTM A 153. Secondary racks shall be light duty galvanized steel with porcelain insulator spools spaced 300 mm (12 in.) apart and secured to the pole by two 16 mm (5/8 in.) through bolts, nuts, and washers, all galvanized.

7. Anchor guy shall be equipped with guy wire protectors.

- (2) Trench and Backfill. Trench and backfill shall be according to Section 815.
- (3) Grounding. Grounding shall meet the requirements of Article 1087.01.
- (4) Conductors. The conductors shall meet the requirements of Article 1066.02.
- (5) Conduit. The conduit shall meet the requirements of Article 1088.01.
- (6) Weatherhead. The weatherhead shall be designed to fit the service conduit size and galvanized according to AASHTO SQ M 32. It shall be furnished with a composition cover with holes for the service cables.
- (7) Service Disconnect Switch. Where metering is installed on the service pole, a service disconnect switch shall be provided on the pole. It shall be enclosed in a NEMA type 3R raintight housing. The switch shall provide for locking in either the "On" or "Off" position. It shall be rated for the proper amperage and voltage to be compatible with the system it is protecting or as shown on the plans. Fuses and padlocks shall be included.

- (b) Underground Electric Service. Underground electric service shall include conduit, cable, trench and backfill, fiberglass above ground pedestal,



disconnect switch and meter base, when metered service is required. It includes all hardware necessary to complete the installation from the power company transformer to the lighting controller. Appropriate material specifications are listed in Overhead Electric Service and shown on the plans.

### **1086.02 Electric Service Installation – Traffic Signal**

- (a) Weatherhead. The weatherhead shall be designed to fit 25 mm (1 in.) threaded conduit, and galvanized according to AASHTO M 232. It shall be furnished with a composition cover with holes for service.
- (b) Circuit Breaker and Weatherproof Enclosure. The circuit breaker shall be single pole, rated 50 A, and mounted on an aluminum plate. The circuit breaker shall be contained in the stainless steel, weatherproof NEMA 4X enclosure of adequate size. The top and bottom of the enclosure shall be furnished with hubs for installing conduits. The enclosure shall be furnished with two padlocks, one for the handle and for the door when used in a Type A service installation. Each padlock shall be furnished with two No. 399 fitted alike keys.
- (c) Grounding. The grounding shall be according to Section 807.

## **SECTION 1087. GROUNDING**

### **1087.01 Grounding for Lighting**

- (a) Grounding Electrode Conductors. Grounding electrode conductors shall be solid, soft drawn 1/C No. 6 copper and shall be installed according to NEC requirements.
- (b) Grounding Electrodes. Grounding electrodes shall be copper-clad steel with a minimum copper thickness of 0.3 mm (10 mils) and UL listed 467. Grounding electrodes shall be one piece, sectional (threaded) steel rods not less than 16 mm (5/8 in.) in diameter and 3 m (10 ft) long.
- (c) Access Wells. Grounding electrode access wells shall be constructed of PVC or composite polyester resin/fiberglass material with a diameter of 200 mm (8 in.) to 300 mm (12 in.), a length of 900 mm (36 in.) and a cast iron or composite polyester resin/fiberglass lid, secured via stainless steel hardware. A concrete handhole may be used for the access well according to Article 1088.10.

**1087.02 Grounding for Traffic Signals.** The grounding shall be according to Section 807.

**SECTION 1088. WIREWAY AND CONDUIT SYSTEM**

**1088.01 Electrical Raceway Materials.**

- (a) Rigid Metal Conduit. The conduit, after fabrication, shall be thoroughly cleaned and the inside and outside surfaces shall be galvanized.

Couplings and fittings shall meet ANSI Standard C 80.1 and shall be hot-dip galvanized. Elbows and nipples shall conform to the specifications for conduit. All fittings and couplings for rigid conduit shall be of the threaded type.

- (1) Rigid Steel Conduit. Rigid steel conduit shall be galvanized and manufactured according to UL Standard 6 and shall meet Federal Specification WWC-581, ANSI Standard C 80.1, and the requirements of NEC Article 346-15.
- (2) Intermediate Metal Conduit. Intermediate metal conduit shall be manufactured according to UL Standard 1424 and shall meet Federal Specification WWC-581 and the requirements of NEC Article 345-16.

After fabrication, the conduit shall be thoroughly cleaned and the inside and outside surfaces galvanized.

Couplings and fittings shall meet ANSI Standard C-80.1 and shall be hot-dipped galvanized. All fittings and couplings for conduit shall be the threaded type.

- (3) PVC Coated Galvanized Steel Conduit. The conduit prior to coating shall meet the requirements for rigid metal conduit and be manufactured according to NEMA Standard No. RN1.

The PVC coating shall have the following characteristics:

Hardness:	85+ Shore A Durometer
Dielectric Strength:	400V/mil @ 60 Hz
Aging:	1,000 Hours Atlas Weatherometer
Temperature:	The PVC compound shall conform at 0 °F to Federal Specifications PL-406b, Method 2051, Amendment 1 of 25 September 1952 (ASTM D 746)
Elongation:	200 percent

The exterior galvanized surfaces shall be coated with a primer before the PVC coating to ensure a bond between the zinc substrate and the PVC coating. The bond strength created shall be greater than the tensile strength of the plastic coating. The nominal thickness of the PVC coating shall be 1 mm (40 mils). The PVC shall pass the following bonding test:

Two parallel cuts 13 mm (1/2 in.) apart and 40 mm (1 1/2 in.) in length shall be made with a sharp knife along the longitudinal axis. A third cut shall be made perpendicular to and crossing the longitudinal cuts at one end. The knife shall then be worked under the PVC coating for 13 mm (1/2 in.) to free the coating from the metal.

Using pliers, the freed PVC tab shall be pulled with a force applied vertically and away from the conduit. The PVC tab shall tear rather than cause any additional PVC coating to separate from the substrate.

A two part urethane coating shall be applied to the interior of the conduit. The internal coating shall have a nominal thickness of 0.05 mm (2 mils). The interior coating shall be applied in a manner so there are no runs, drips, or pinholes at any point. The coating shall not peel, flake, or chip off after a cut is made in the conduit or a scratch is made in the coating. The urethane interior coating applied shall afford sufficient flexibility to permit field bending without cracking or flaking of the interior coating.

All conduit fittings and couplings shall be as specified and recommended by the conduit manufacturer. All conduit fitting covers shall be furnished with stainless steel screws which have been encapsulated with a polyester material on the head to ensure maximum corrosion protection.

- (4) Liquid Tight Flexible Metal Conduit. Liquid-tight flexible metal conduit shall be manufactured according to UL Standard 360. The conduit shall have a temperature range of -20 °C to +60 °C (-4 °F to 140 °F). The thermoplastic covering shall be oil resistant. Conduit shall have an integral copper core for current carrying purposes or have a copper ground wire embedded in the sheath.
- (5) Aluminum Conduit. Aluminum conduit shall be manufactured of 6063 aluminum alloy, T-1 temper, according to UL Standard 6 and shall meet Federal Specification WW-C-540c, ANSI Standard C-80.5 and the requirements of N.E.C. Article 346-15.
- (b) Rigid Nonmetallic Conduit. The conduit, fittings, and accessories shall be manufactured from polyvinyl chloride complying with ASTM D 1784 and with all the applicable requirements of NEMA Publication No. TC2, UL Standard 651 for EPC-40-PVC and NEC Article 347.

Fittings and accessories for the electrical plastic conduit shall comply with all applicable requirements of NEMA Publication No. TC3.

The solvent cement used to join the conduit and fittings shall be according to ASTM D 2564.

- (c) Coilable Nonmetallic Conduit.

Polyethylene Duct. The duct shall be a plastic duct which is intended for underground use and can be manufactured and coiled or reeled in continuous transportable lengths and uncoiled for further processing and/or installation without adversely affecting its properties of performance. The duct and its manufacture shall conform to the standards of NEMA Publication No. TC-7 and ASTM D 3485.

The duct shall be made of high density polyethylene which shall meet the requirements of ASTM D 1248, Type III Class C and the requirements listed in Table 2-1 of NEMA Standard Publication No. TC-7.

Duct dimensions shall conform to the standards listed in Table 2-2 of NEMA Standard Publication No. TC-7.

Performance Tests. Polyethylene Duct testing procedures and test results shall meet the requirements of NEMA Standard Publication No. TC 7 Part 3. Certified copies of the test report shall be submitted to the Engineer prior to the installation of the duct.

#### **1088.02 Expansion Fittings for Raceways.**

- (a) Expansion couplings for metallic raceways shall consist of a 200 mm (8 in.) expansion fitting plus a deflection fitting which allows for a 20 mm (3/4 in.) deflection. All couplings except those used indoors shall have a bonding jumper. Couplings used indoors shall be listed for use without a bonding jumper. Bonding jumpers for exposed metallic raceways shall be external. The coupling may be a combination of the two fittings or a single fitting assembly.
- (b) Non-metallic Couplings. Expansion coupling for non-metallic raceways shall be made of PVC and consist of a 200 mm (8 in.) expansion fitting plus a deflection fitting which allows for a 20 mm (3/4 in.) deflection. The coupling may be a combination of the two fittings or a single fitting assembly.

**1088.03 Fasteners and Hardware.** Fasteners used to mount conduit supports, boxes, and other items attached to the structure shall be suitable for the weight supported and shall be compatible with the structure material. Wood screws shall be used for wood, toggle bolts shall be used for hollow masonry, expansion bolts or power-set studs shall be used for solid masonry or concrete, and clamps shall be used for structural steel.

Expansion anchors and power set anchors shall not be less than 6 mm (1/4 in.) diameter and shall extend at least 50 mm (2 in.) into the masonry or concrete.

All steel hardware shall be hot-dipped galvanized. Hardware for stainless steel boxes and other stainless steel items shall be stainless steel.

Screws for the attachment of pole handhole covers, covers on cast metal boxes, doors on transformer bases, and other such applications shall be stainless steel

unless otherwise specified. Anti-seize compound shall be used to treat all junction box and pole handhole hardware.

**1088.04 Stainless Steel Junction Box.** The box shall be made of Type 304 stainless steel, not less than 2.03 mm (14 gauge), with all seams continuously welded with stainless steel weld wire and ground smooth. Exterior surfaces shall have a smooth polished finish. The box shall be UL 50 "Junction and Pull Box", "Junction Box", or "Pull Box".

A grounding lug shall be provided for the connection of the equipment grounding conductors as required by NEC Article 250-114.

When specified for attachment to a structure, the box shall:

Conform to NEMA Type 4X.

Have an overlapping stainless steel cover and shall be secured to the box with a continuous stainless steel hinge and a minimum of four captive stainless steel clamps utilizing captive stainless steel hex-head bolts or deep slotted stainless steel screws.

Be suitable for surface mounting, complete with external stainless steel mounting lugs or brackets welded to the enclosure.

The box cover shall have a continuous formed, seamless, urethane, oil-resistant gasket. The gasket shall be placed directly onto the junction box cover. The gasket shall adhere to the cover without the use of adhesives. A neoprene strip gasket, or urethane strip gasket cut out of a larger sheet and glued to the junction box will not be acceptable.

When specified for embedment in structure, the box shall be constructed to NEMA 4X standards, with an oil-resistant gasket between the body and cover and with the cover arranged to fit flush with the structure surface. The cover shall be attached with stainless steel unslotted hex-head screws. Cover shall be furnished with retaining chain and captive screws when mounted on bridge structures.

**1088.05 Composite Concrete Junction Box.** The cover of the junction box shall be arranged to fit flush with the structure surface. The cover shall be attached with stainless steel hex-head bolts factory coated with anti-seize compound.

The box and cover shall be constructed of a polymer concrete and reinforced with a heavy-weave fiberglass cloth. The material shall have the following properties:

compressive strength, 75,800 kPa (11,000 psi)  
tensile strength, 11,700 kPa (1700 psi)  
flexural strength 51,700 kPa (7500 psi).

The resulting enclosure shall have a service load of 35.6 kN (8,000 lb), (minimum), over a 250 mm (10 in.) square area as defined by ASTM C 857. The material shall have light gray color to match the surrounding concrete. The cover shall be made of the same material.

Conduit openings may be factory cut and preassembled with conduit fittings. Conduit fittings and accessories shall be manufactured from polyvinyl chloride complying with ASTM D 1784 and shall comply with all the applicable requirements of NEMA Publication No. TC2, U.L. Standard 651 for EPC-40-PVC and NEC Article 347.

Slight deviations to a larger size than the specified sizes may be allowed to conform to a standard manufacturer's production size with the approval of the Engineer.

**1088.06 Concrete Junction Box.** The box shall be constructed with Class SI Concrete conforming to Section 1020. The dimension and wall thickness of the box shall be as detailed on the plans.

The cover for the junction box shall be made of cast iron conforming to the requirements of AASHTO M 105, Class 30 or better, or steel. The cover for the junction box shall be designed to withstand AASHTO H-15 loading. The cover shall have a legend "IDOT LIGHTING" or "TRAFFIC SIGNALS" when used for highway lighting or traffic signals respectively.

The cover shall be fastened to the junction box with stainless steel bolts or screws conforming to the requirements of Article 1006.31. A heavy-duty gasket shall be provided between the cover and the box for a watertight seal.

**1088.07 Cast Iron Junction Box.** The box shall be made of cast iron, hot dip galvanized, and UL listed, NEMA 4.

When specified for attachment to structure, the box shall be suitable for surface mounting, complete with external mounting lugs integral to the casting and shall have a gasketed flange cover. Mounting lugs shall be integral with or securely attached to the box, maintaining the NEMA 4 rating and galvanizing shall be done after the lugs are attached.

When specified for embedment, the box shall be suitable for encasement in concrete with a flush gasketed cover, recessed within an outside flange frame. When embedded, the junction box does not require mounting lugs.

Covers shall be attached with hex-head unslotted silicon bronze screws. The Engineer will determine the application of screws based on the box location.

**1088.08 Reinforced Plastic Mortar Junction Box.**

- (a) The Box. The box shall be constructed of a polyester resin concrete and reinforced with a heavy weave fiberglass cloth. The material shall have the following mechanical properties:

Compressive strength 75,800 kPa (11,000 psi)  
Tensile strength 11,700 kPa (1,700 psi)  
Flexural strength 51,700 kPa (7,500 psi)

The dimension and wall thickness of the box shall be as detailed on the plans.

- (b) The Cover. The cover for the junction box shall be made of cast iron according to AASHTO M 105, Class 30 or better, or steel according to the requirements of Article 1006.04. The cover for the junction box shall be designed to withstand AASHTO H 20 loading. The cover shall have a legend "IDOT LIGHTING" or "TRAFFIC SIGNALS" when used for highway lighting or traffic signals respectively.

A heavy duty gasket shall be provided between the cover and the box for a watertight seal.

The cover shall be fastened to the junction box with stainless steel bolts or screws according to the requirements of Article 1006.31.

**1088.09 Galvanized Steel Junction Box.** The box be made of galvanized steel and shall meet the requirements of NEMA 3R and be UL listed. It shall be to hot dipped galvanized according to ASTM A526 to provide a corrosion resistant coating.

When specified for attachment to a structure it shall be suitable for both concrete embedment or surface mounting. The junction box shall be furnished with a cover, gasket and hardware. Hardware furnished for the cover shall be stainless steel. All bridge mounted junction boxes shall be furnished with a retaining chain and captive screws.

**1088.10 Handhole.**

- (a) Concrete. The concrete shall be Class SI according to Section 1020.
- (b) Composite Concrete. The composite concrete shall be according to Article 1088.05.

All hardware used for assembling the composite concrete double handhole shall be galvanized or stainless steel.

- (c) Frame and Cover. The handhole frame and cover shall be fabricated from steel according to Section 505, or cast iron according to AASHTO M 105, Class 30 or better. The dimensions of the frame and cover shall be according to Standards 814001 and 814006, and the frame and the outer rims of the cover shall be a minimum of 19 mm (3/4 in.) thick. The thickness of the cover, at the center, shall be a minimum of 25 mm (1 in.) at the reinforcing ribs. The frame and cover shall have beveled edges to assist in centering the cover. Each cover of a double handhole shall be connected to the frame by a flush hinge.

The outside of the cover shall contain a recessed ring or handle for lifting and a cast in place legend "TRAFFIC SIGNALS" or "IDOT LIGHTING" when used for traffic signals or highway lighting respectively. The frame and cover shall be designed to withstand AASHTO H 15 loading for a regular handhole

and a double handhole, and to withstand AASHTO H 20 loading for a heavy-duty handhole. The frame and cover of a handhole shall have the minimum mass (weight) as follows:

Frame and Cover	Minimum Mass (Weight)
Handhole	64 kg (140 lb)
Heavy-duty Handhole	118 kg (260 lb)
Double Handhole	150 kg (330 lb)

- (d) Lift Ring. The handhole lift ring shall have the same or better design life than the handhole cover and frame. The attachment of the lift ring to the lid by a loaded spring mechanism will not be acceptable.
- (e) French Drain. The French drain shall be constructed of crushed stone or gravel, Gradation CA 5 or CA 7, and according to Section 601.

SECTION 1089. RESERVED

SIGNS

SECTION 1090. SIGN BASE

1090.01 Sign Base Material Requirements.

TABLE 1 MATERIAL REQUIREMENTS - SIGN BASE			
Sign Type	Reflectorized Sign Face Refelectorzied Sign Legend	Reflectorized Sign Face Nonreflectorzied Sign Legend	Nonreflectorized Sign Face Nonreflectorzied Sign Legend
Type 1 <sup>1/</sup>	Sheet Aluminum	Sheet Aluminum	Sheet Aluminum
Type 2 <sup>2/</sup>	Sheet Aluminum or Bolted Aluminum Extrusions or Plywood <sup>4/</sup>	Sheet Aluminum Or Bolted Aluminum Extrusions Or Plywood <sup>4/</sup>	Sheet Aluminum or Bolted Aluminum Extrusions or Plywood <sup>4/</sup>
Type 3 <sup>3/</sup>	Bolted Aluminum Extrusions	Bolted Aluminum Extrusions	

1/ 1.8 m (6 ft) wide or less and 0.84 sq m (9 sq ft) in area or less.



- 2/ Over 0.84 sq m (9 sq ft) in area or over 1.8 m (6 ft) wide but less than 2.22 sq m (24 sq ft).
- 3/ 2.22 sq m (24 sq ft) in area or larger.
- 4/ Only when specified.

Note: On freeways and expressways, Type 2 panels used for guide, information, or service signing shall have the same sign legend as the Type 3 sign panels.

**1090.02 Sheet Aluminum.** The sign base material shall be flat sheet aluminum to which a chemical conversion coating has been applied. The material shall comply with ASTM B 209, Alloy 6061-T6 or 5052-H 38 and conversion coated according to either MIL-C-5541 or ASTM-B-449.

Type 1 sign panels shall be at least 2.03 mm (0.080 in.) thick. Type 2 sign panels shall be at least 3.17 mm (0.125 in.) thick. All panels shall be a flat continuous section of the length, width and shape specified in the plans for Standard Sign Design Criteria of the MUTCD with specified mounting holes and corner radii. Sign panels shall conform to dimensions specified, within  $\pm 0.794$  mm (1/32 in.) and shall not be out of square more than 1.588 mm (1/16 in.). Warps and buckles shall not exceed 1.588 mm (1/16 in.) for each foot in length or width when laid on a true flat surface. All fabrication shall be accomplished prior to the chemical conversion coating process.

Before reflective sheeting or paint is applied to the sign panel, the application surface shall be thoroughly cleaned, prepared or etched according to the sheeting or paint manufacturer's recommendations. The chemical conversion coating shall remain intact on the backside of the sign panel. There shall be no opportunity for the clean metal surface to oxidize or come in contact with grease, oils, or other contaminants prior to the application of reflective sheeting or paint.

**1090.03 Bolted Aluminum Extrusions.** Sign panels of this type shall be made of aluminum conforming to ASTM B 221, Alloy 6063-T 6.

Panel preparation shall comply with Article 1090.02, except etching may be omitted and holes for demountable sign legend units may be drilled after assembly and reflectorization.

Sign molding shall be an aluminum extrusion designed for the sign panel extrusion with which it is to be used and its color shall match the color of the sign background. The sign molding shall be riveted to the sign panel on 600 mm (2 ft) centers.

Aluminum dome head rivets shall be used to secure the sign molding, sign panel overlays, demountable legend unit, and supplemental panel to the sign face. The dome head rivets shall be 4.75 mm x 6.35 mm (3/16 in. x 1/4 in.) blind made from 5052 aluminum with an aluminum alloy mandrel. The dome head rivets shall have a grip range from 3.2 to 11.4 mm (0.126 to 0.250 in.) with a flange diameter of 2.9 mm (0.114 in.) and a rivet length of 11.4 mm (0.450 in.). The dome head rivets shall be color anodized to conform to the sheeting color of the unit being installed.

All bolts, nuts, and other hardware and material used in assembling aluminum extrusions into sign panels shall be stainless steel and shall be supplied by the manufacturer of the panels.

Stainless steel post clips shall conform to ASTM 276, Type 304. A flat washer shall be used under each nut to prevent gouging of the clip.

Stainless steel bolts, nuts, and washers used for fastening extruded aluminum sign panels to supports, shall conform to ASTM A 276, Type 304. Nuts shall conform to A 240, Type 304. Stainless steel bolts, nuts, and washers shall be used with aluminum post clips when installing overhead mounted sign panels.

**1090.04 Plywood.** Plywood furnished under this specification shall conform to the specified requirements of U.S. Product Standard PS 1-83, dated December 30, 1983, or hereafter referred to as PS 1-83. Each panel shall bear the mark of an approved testing agency or independent testing laboratory.

Plywood sign panels shall conform to the provisions of Section 3.4 of PS 1-83, except the inner plies may be made of plugged "C" quality veneers of Group 2 species. Both faces of the panels shall be "B" quality veneers of Group 1 species. The plywood shall have a nominal thickness of 19 mm (3/4 in.).

Both faces shall be high density overlay natural (buff), 60/60, in conformance with Section 3.6.8.1 of PS 1-83. Sign panel edges shall be smooth, straight, and free from tears and splinters, and the edges shall be sealed with two coats of aluminum paint conforming to Article 1008.19.

The plywood signs shall be square and free from warp and shall conform to Section 3.10 of PS 1-83.

If slip sheets are used, they must not deposit any wax, silicone, or other substance on the surface of the overlays.

There must be no caulk lubricant residue left on the surface of the overlays that will affect the adhesion of paint or reflective sheeting.

Plywood sign panels shall not be used with Type A reflective sheeting.

**SECTION 1091. SIGN FACE****1091.01 Sign Face Material Requirements.**

TABLE 1 MATERIAL REQUIREMENTS - SIGN FACE			
Sign Type	Reflectorized Sign Face Refectorized Sign Legend	Reflectorized Sign Face Nonreflectorized Sign Legend	Nonreflectorized Sign Face Nonreflectorized Sign Legend
Type 1 <sup>1/</sup>	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	Nonreflective Sheeting or Enamel Paint
Type 2 <sup>2/</sup>	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	Reflective Sheeting or Enamel Paint
Type 3 <sup>3/</sup>	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B	

- 1/ 1.8 m (6 ft) wide or less and 0.84 sq m (9 sq ft) in area or less.  
 2/ Over 0.84 sq m (9 sq ft) in area or over 1.8 m (6 ft) wide but less than 2.22 sq m (24 sq ft).  
 3/ 2.22 sq m (24 sq ft) in area or larger.  
 4/ Only when specified.

Note: On freeways and expressways, Type 2 panels used for guide, information, or service signing shall have the same sign legend as the Type 3 sign panels.

**1091.02 Reflective and Nonreflective Sheeting.** The sheeting shall form a durable bond to smooth corrosion and weather-resistant surfaces and adhere securely at temperatures of -34 to 71 °C (-30 to 160 °F). When subjected to any temperature within this range, the sheeting shall not crack, chip, or peel voluntarily, nor shall it be removable from the panel in one piece without the aid of a tool. The precast adhesive, 48 hours after application, shall be elastic enough, at low temperatures, to resist shocking off when struck at -23 °C (-10 °F), vandal resistant, and strong enough to resist appreciable peeling. The bond shall be sufficient to support a 0.8 kg mass (1 3/4 lb weight) attached to the free end of a specimen and allowed to hang free from an angle of 90 degrees to the panel surface for five minutes without peeling more than 50 mm (2 in.) as outlined in the test for adhesive backing Federal Specifications L-S-300.

The sheeting color shall conform to the latest appropriate standard color tolerance chart issued by the U.S. Department of Transportation, Federal Highway Administration.

The sheeting shall have a protective liner and either a precoated pressure sensitive adhesive (Type 1), a tack free, heat activated adhesive (Type II), or a positionable pressure sensitive adhesive (Type III), each of which must be capable of being applied without additional adhesive coats on the reflective sheeting or application surface.

The Contractor shall provide certification from an independent testing laboratory approved by the Department stating the material to be furnished meets all requirements of these specifications. The certification shall be forwarded to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766. The Department reserves the right to require three 330 mm (13 in.) by 330 mm (13 in.) samples representative of each color of material to be used. Any or all material may be rejected if the tests performed on these samples indicate failure to meet these specifications.

The Department also reserves the right to inspect any completed sign face and reject any or all signs if the inspection indicates failure to meet these specifications.

(a) Reflective.

Type A reflective sheeting shall consist of glass spherical lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, plastic having a smooth outer surface.

Types AA and AP reflective sheeting shall consist of a flexible colored, cube corner prismatic retroreflective material having a smooth outer surface.

Types BB, B, and C reflective sheeting shall consist of glass spherical lens elements embedded within a flexible, transparent, plastic film having a smooth, flat outer surface.

The reflective sheeting color shall conform to the latest appropriate standard color tolerance chart issued by the U.S. Department of Transportation, Federal Highway Administration and to the daytime color requirements of ASTM D 4956.

The reflective sheeting shall have the minimum brightness values shown in Table 1091-2 for the type and color of material specified. The reflective intensity shall be determined by the procedures described in ASTM E 810.

The brightness of the reflective sheeting totally wet shall not be less than 90 percent of the reflective values shown in Table 1091-2 when tested in conformance with the procedure outlined in Section 7.10.1 of AASHTO M 268.

The thickness of the reflective sheeting without protective liner shall not be more than 0.4 mm (0.015 in.) for Type A, BB, B, and C and not more than 0.6 mm (0.025 in.) for Type AA and AP.

When tested according to Section 4.3.15 of Federal Specification L-S-300, the reflective sheeting with the liner removed shall have a tensile strength between 0.9 N and 4.4 N/mm (5 lb and 25 lb/in.) of width.

Following removal of the protective liner, the reflective sheeting shall not shrink more than 0.8 mm (1/32 in.) in ten minutes nor more than 3.2 mm (1/8 in.) in 24 hours in any dimension per 225 mm (9 in.) square at  $24 \pm 4^\circ\text{C}$  ( $75 \pm 5^\circ\text{F}$ ) and  $50 \pm 5$  percent relative humidity.

Type A, AA and AP sheeting with the liner removed and conditioned for 24 hours at  $22 \pm 4^\circ\text{C}$  ( $72 \pm 5^\circ\text{F}$ ) and  $50 \pm 5$  percent relative humidity shall be sufficiently flexible to show no cracking when slowly bent, in one second's time, around a 3.2 mm (1/8 in.) mandrel with adhesive contacting the mandrel (the adhesive may be coated with talcum powder to prevent sticking).

Types BB, B, and C sheeting, when applied according to manufacturer's recommendations to cleaned and etched 0.5 mm (0.020 in.) by 50 mm (2 in.) by 200 mm (8 in.) aluminum (Alloy 6061-T6) sections conditioned for 48 hours, and tested at  $22 \pm 4^\circ\text{C}$  ( $72 \pm 5^\circ\text{F}$ ) and  $50 \pm 5$  percent relative humidity, shall be sufficiently flexible to show no cracking when bent around a 19 mm (3/4 in.) mandrel.

The reflective material shall be processed and applied directly to properly prepared sign bases according to the sheeting manufacturer's recommended procedures. The reflective material shall be weather resistant and, following cleaning, shall show no appreciable discoloration, cracking, crazing, blistering, or dimensional change and shall meet the requirements shown in Table 1091-2 when exposed to the corresponding hours of accelerated weathering shown. The test specimens shall be cleaned by immersing in five percent hydrochloric acid 45 seconds, rinsing with water and blotting dry with a soft clean cloth. The Recommended Practice for Operating Light-and-Water Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials, ASTM G53 shall govern the weathering testing. The cycle used shall consist of eight hours of light at  $60^\circ\text{C}$  ( $140^\circ\text{F}$ ) followed by four hours of condensation at  $40^\circ\text{C}$  ( $104^\circ\text{F}$ ).

Accelerated Weathering  
Minimum

<u>Material</u>	<u>Exposure Time</u>	<u>Brightness</u>
Types AA, AP & A	*1,000 hours	80% Table 1091-2
Type BB	*1,000 hours	65% Table 1091-2
Type B	500 hours	50% Table 1091-2
Type C	300 hours	50% Table 1091-2

\*Orange Types A and BB and fluorescent orange Types AA and AP shall have an exposure time of 300 hours.

Types A, AA, and AP sheeting shall permit cutting and color processing according to the sheeting manufacturer's recommendations at temperatures of 15 to 38 °C (60 to 100 °F) and relative humidity of 20 to 80 percent. The sheeting shall be heat resistant and permit forced curing without staining of applied or unapplied sheeting at temperatures recommended by the manufacturer. The sheeting shall be solvent resistant and capable of being cleaned with VM&P naphtha, mineral spirits, and turpentine.

Types BB, B, or C sheeting shall be such that cutting and color processing at temperatures 10 to 43 °C (50 to 110 °F) and relative humidities of 20 to 80 percent will be possible. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures up to 66 °C (150 °F) and up to 93 °C (200 °F) on applied sheeting. The sheeting surface shall be solvent resistant and may be cleaned with VM&P naphtha, mineral spirits, turpentine, methanol, or xylol.

The sheeting surface shall exhibit an 85 degree gloss-meter rating of not less than 50 for Types A, AA, AP and BB and 40 for Type B when tested according to ASTM D 523.

Sign faces for all Interstate Route shields (M1-1), auxiliary plates having a blue background with white legend (M2 , 3, 4, 5, and 6), red Type 1 object markers and all STOP (R1-1), YIELD (R1-2), ALL-WAY (R1-4), do not enter symbol (R5-1), WRONG WAY (R5-9), chevron alignment (W1-8), STOP AHEAD (W3-1), (W3-1a), YIELD AHEAD (W3-2a), RAILROAD ADVANCE WARNING (W10-1), and NO PASSING ZONE (W14-3) shall be fabricated with faces of Type A reflective sheeting. Mast arm mounted street name signs shall be fabricated with faces of Type A or Type BB reflective sheeting. All route shields and auxiliary panels mounted on signs with Type A reflective sheeting faces shall also have Type A reflective sheeting.

On fully access-controlled sections of highway (freeways or expressways), all reflectorized signs and supplemental panels, except green guide signs, shall be fabricated using faces of Type A or AP reflective sheeting. Green guide sign faces shall be fabricated using Type BB or better sheeting. When Type BB sheeting is used for green sign faces the legend shall be fabricated using Type A or AP sheeting. When Type A, AP or better sheeting is used for guide sign faces, the sign faces and legends shall be fabricated with reflective material by the same manufacturer. This shall include mainline, ramp, crossroad interchange approach directional signing, route markers, and all signs within the interchange.

Sign faces, legend, overlay, or supplemental panels shall not be fabricated with Type C reflective sheeting.

All warning signs (W series), all SPEED LIMIT (R2-1), SPEED ZONE AHEAD (R2-5C), advisory speed (R2-1101), and all green destination and information (D and I series) signs not otherwise specified shall be fabricated with faces of Type A or Type BB reflective sheeting.

Sign faces comprising two or more pieces or panels of reflective sheeting must be carefully matched for color at the time of sign fabrication to provide uniform appearance and brilliance, both day and night. Successive width sections of either sheeting or panels must be consecutively reversed to ensure corresponding edges of reflective sheeting lie adjacent on the finished sign. Nonconformance may result in rejection of the sign face.

At splices, Type I and Type III adhesive coated sheeting shall be overlapped not less than 4.8 mm (3/16 in.). Type II adhesive coated sheeting may be spliced using an overlap splice of not less than 4.8 mm (3/16 in.) or butted with a gap splice not exceeding 0.8 mm (1/32 in.). Only butt splices will be permitted on signs screen-processed with a transparent color using Type BB, B, or C sheeting materials. Only overlap splices will be permitted on signs screen-processed with translucent color using Type A, AA and AP sheeting material.

Types A, AA, AP and BB sheeting shall have a distinctive overall permanent identifying symbol (watermark) unique to the individual manufacturer incorporated into the sheeting and shall be visible to the naked eye within 0.9 m (3 ft) without the use of special devices. The symbol shall repeat at intervals no greater than 203 mm (8 in.) both vertically and horizontally. A distinctive overall pattern in the sheeting unique to the individual manufacturer may be used in lieu of a symbol. Neither the symbol or the overall pattern shall interfere with the reflectivity of the sheeting. If material orientation is required for optimum retroreflectivity, permanent marks indicating direction of orientation shall be incorporated into the face of the sheeting and shall be readily visible to the sign fabricator.

Where recommended by the manufacturer, reflective sheeting shall be coated with a full glossy coat of clear finish, approved by the sheeting manufacturer.

Table 1091-2

Minimum Coefficient of Retroreflection  
Average Candelas/Lux/sq m (candelas/foot candle/sq ft) of Material

Color	Type AA (0 and 90 degree Rotation Angles)			
	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle -4	Entrance Angle +30	Entrance Angle -4	Entrance Angle +30
White	800.0	400.0	200.0	100.0
Yellow	660.0	340.0	160.0	85.0
Orange*	200.0	120.0	80.0	50.0
Red	215.0	100.0	45.0	26.0
Green	75.0	30.0	18.0	10.0
Blue	43.0	20.0	9.8	5.0
Brown	N/A	N/A	N/A	N/A

(45 degree Rotation Angle)

Yellow	550.0	130.0	145.0	70.0
Orange*	165.0	45.0	70.0	40.0

\*Fluorescent Orange

Type AP

Color	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle		Entrance Angle	
	-4	+30	-4	+30
White	250.0	80.0	135.0	55.0
Yellow	170.0	54.0	100.0	37.0
Orange*	105.0	30.0	60.0	22.0
Red	35.0	9.0	17.0	6.5
Green	35.0	9.0	17.0	6.5
Blue	20.0	5.0	10.0	3.5
Brown	7.0	2.0	4.0	1.4

\*Fluorescent Orange

Type A

Color	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle		Entrance Angle	
	-4	+30	-4	+30
Silver/White	250.0	150.0	95.0	75.0
Yellow	170.0	100.0	65.0	50.0
Orange	100.0	60.0	30.0	25.0
Red	45.0	25.0	15.0	10.0
Green	45.0	25.0	15.0	10.0
Blue	20.0	12.0	8.0	5.0
Brown	12.0	8.5	5.0	3.5

Type BB

Color	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle		Entrance Angle	
	-4	+30	-4	+30
Silver/White	140.0	60.0	50.0	28.0
Yellow	100.0	36.0	33.0	20.0
Orange	60.0	22.0	20.0	12.0
Red	30.0	12.0	10.0	6.0
Green	30.0	10.0	9.0	6.0
Blue	10.0	4.0	3.0	2.0
Brown	5.0	2.0	2.0	1.0



## Type B

Color	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle		Entrance Angle	
	-4	+30	-4	+30
Silver/White	90.0	40.0	41.0	21.0
Yellow	60.0	30.0	25.0	13.0
Orange	30.0	12.0	15.0	10.0
Red	16.5	8.0	8.0	5.0
Green	11.0	5.0	5.0	2.5
Blue	5.0	2.0	2.5	0.8
Brown	3.0	1.0	1.5	0.6

## Type C

Color	Observation Angle 0.2		Observation Angle 0.5	
	Entrance Angle		Entrance Angle	
	-4	+30	-4	+30
Silver/White	50.0	12.0	15.0	6.0
Yellow	25.0	7.0	10.0	3.0
Orange	25.0	5.8	12.5	3.0
Red	10.0	3.0	5.0	1.0
Green	5.0	2.0	3.0	1.0
Blue	4.0	1.0	2.0	0.5
Brown	1.0	0.1	--	--

## (b) Nonreflective Sheeting

The nonreflective sheeting shall consist of a flexible, pigmented plastic film completely precoated with an adhesive, protected by a liner and shall meet the following requirements:

The thickness of the sheeting without a protective liner shall be a minimum of 0.07 mm (0.003 in.) and a maximum of 0.13 mm (0.005 in.).

The sheeting shall have an average initial 60 degree glossmeter value of at least 40 when tested according to ASTM D 523, measuring at least three portions of the film to obtain uniformity.

Test panels shall be prepared using 165 mm x 165 mm (6 1/2 in. x 6 1/2 in.) pieces of sheeting premasked as recommended by the manufacturer to an aluminum panel according to Article 1090.02, trimmed evenly at the edges of the panel, and aged for 48 hours at 21 to 32 °C (70 to 90 °F).

The sheeting shall not shrink more than 0.4 mm (1/64 in.) from any panel edge when the test panel is subjected to a temperature of 66 °C (150 °F) for 48 hours and shall be sufficiently heat resistant to retain adhesion after one week at 66 °C (150 °F).

Unprocessed sheeting that has been exposed to the elements shall show no appreciable discoloration, cracking, crazing, blistering, delamination, or loss of adhesion, according to the following type of adhesion and length of exposure:

Type I and III Adhesive Sheeting - seven years

Type II Adhesive Sheeting - five years

A slight amount of chalking is permitted but the sheeting shall not support fungus growth.

The test panels, when immersed to a depth of 50 to 75 mm (2 to 3 in.) in the following solutions at 21 to 32 °C (70 to 90 °F) for the specified times and examined one hour after removal, shall show no appreciable decrease in adhesion, color, or general appearance.

Solution	Hours Immersion
Reference Fuel (MIL-F-8799A) (15 parts xylol and 85 parts Mineral spirits by weight)	1
Distilled Water	24
SAE No. 20 Motor Oil	24
Antifreeze (1/2 ethylene glycol, 1/2 distilled water)	24

**1091.03 Enamel Paint.** Enamel paint shall meet the recommendations of the manufacturer of the sign background material, except the color shall be as specified on the plans and shall conform to the color tolerance chart issued by the U.S. Department of Transportation, Federal Highway Administration.

**SECTION 1092. SIGN LEGEND AND SUPPLEMENTAL PANELS****1092.01 Material Requirements.**

TABLE 1 MATERIAL REQUIREMENTS - SIGN LEGEND			
Sign Type	Reflectorized Sign Face Refectorzied Sign Legend	Reflectorized Sign Face Nonreflectorzied Sign Legend	Nonreflectorized Sign Face Nonreflectorzied Sign Legend
Type 1 <sup>1/</sup>	Direct Applied Reflective Sheeting Types A, AA, AP, AZ, BB <sup>4/</sup> or B <sup>4/</sup> or Transparent Silk Screen Inks	Direct Applied Nonreflective Sheeting or Opaque Silk Screen Inks	Direct Applied Nonreflective Sheeting or Opaque Silk Screen Inks
Type 2 <sup>2/</sup>	Direct Applied Reflective Sheeting Types A, AA, AP, AZ, B <sup>4/</sup> or Type A Reflective Sheeting on Flat Frames or Transparent Silk Screen Inks	Direct Applied Nonreflective Sheeting or Nonreflective Sheeting on Flat Frames or Opaque Silk Screen Inks	Direct Applied Nonreflective Sheeting or Nonreflective Sheeting on Flat Frames or Opaque Silk Screen Inks
Type 3 <sup>3/</sup>	Reflective Sheeting on Flat Frames Types A, AA, AP, AZ	Reflective Sheeting on Flat Frames	

1/ 1.8 m (6 ft) wide or less and 0.84 sq m (9 sq ft) in area or less.

2/ Over 0.84 sq m (9 sq ft) in area or over 1.8 m (6 ft) wide but less than 2.22 sq m (24 sq ft).

3/ 2.22 sq m (24 sq ft) in area or larger.

4/ Only when specified.

Note: On freeways and expressways, Type 2 panels used for guide, information, or service signing shall have the same sign legend as the Type 3 sign panels.

TABLE 2 MATERIAL REQUIREMENTS - SUPPLEMENTAL PANELS			
Sign Type	Reflectorized Sign Face Refectorzied Sign Legend	Reflectorized Sign Face Nonreflectorzied Sign Legend	Nonreflectorized Sign Face Nonreflectorzied Sign Legend
Type 2 <sup>1/</sup>	Reflective Sheeting Types A <sup>3/</sup> , AA, AP, AZ, B or BB <sup>3/</sup>	Reflective Sheeting Types A <sup>3/</sup> , AA, AP, AZ, B or BB <sup>3/</sup>	Nonreflective Sheeting or Enamel Paint (1091.02)
Type 3 <sup>2/</sup>	Reflective Sheeting Types A, AA, AP, AZ, B or BB <sup>3/</sup>	Reflective Sheeting Types A, AA, AP, AZ, B or BB <sup>3/</sup>	

1/ Over 0.84 sq m (9 sq ft) in area or over 1.8 m (6 ft) wide but less than 2.22 sq m (24 sq ft).

2/ 2.22 sq m (24 sq ft) in area or larger.

3/ Only when specified.

Note: On freeways and expressways, Type 2 panels used for guide, information, or service signing shall have the same sign legend as the Type 3 sign panels.

**1092.02 General.** Letters and numerals used shall conform to the standard alphabets for highway signs (available from the Federal Highway Administration) of the series indicated in the design details for the sign.

When uppercase and lowercase letters and related numerals are called for, they will be Series E of the standard alphabets modified by widening the stroke width to approximately one-fifth the letter or numeral height. A suitable design for the lowercase alphabet is also available from the Federal Highway Administration.

When capital letters and related numerals are called for, they will be Series D of the standard alphabet modified by widening the stroke width to approximately one-fifth of the letter or numeral height. Lowercase letters are not used with capital letters.

Each demountable legend unit, supplemental panel, and border frame shall be supplied with mounting holes and shall be secured to the sign face with aluminum dome head rivets with aluminum mandrels and may not be held in place, even temporarily, using any type of adhesive that would damage the sign face, legend unit or border when removed at a later date. All rivets shall be color matched to the legend or supplemental panel being installed.

When recommended by the sheeting manufacturer, the completed demountable legend units, supplemental panels, and borders shall be coated with finishing clear as approved by the sheeting manufacturer. Finishing clear shall be applied to the

sheeting surface in a manner to assure a fully glossy coat and a complete edge seal of the sheeting.

The finished letters, numerals, symbols, panels, and borders shall show careful workmanship and be clean cut, sharp, and have essentially a plane surface.

- (a) Direct Applied Legend. All direct applied sign legend and borders shall be affixed to clean, dust-free sign panels in a manner specified by the legend manufacturer. The legend and border shall be cut neatly at any intersecting panel edge.

Direct applied reflective sheeting, Type A, Type B or Type BB and nonreflective sheeting used for legend and border shall be according to Article 1091.02.

The sheeting may be manufactured with a thin aluminum layer between the sheeting and the precoated adhesive.

- (b) Flat Frames. The reflective sheeting Type A and nonreflective sheeting used on flat frames for legend and border shall be according to Article 1091.02.

Flat frames shall be 0.8 mm (0.032 in.) aluminum according to ASTM B 209, Alloy 3003-H 14. The frames shall be properly degreased and etched and treated with a light, tight, amorphous chromate type coating before any sheeting is applied.

- (c) Supplemental Panels. All supplemental panels shall consist of 2 mm (0.080 in.) sheet aluminum according to Article 1090.02 with reflective sheeting applied according to Article 1091.02.
- (d) Transparent and Opaque Silk Screen Inks. The silk screen inks shall be according to the recommendations of the manufacturer of the sign background material and be applied according to the ink manufacturer's recommendation.

## **SECTION 1093. SIGN SUPPORTS**

### **1093.01 Supports.**

- (a) Structural Steel. Steel shall have a silicone content suitable for galvanizing.
  - (1) Breakaway. All structural steel shall be according to AASHTO M 183M (M 183).

After fabrication, the post, fuse plate, base plate, and upper 150 mm (6 in.) of the stub post shall be galvanized according to AASHTO M 111. Bolts and nuts on the fuse plates may be plated according to ASTM B 633M (B 633) SC3 and then painted with an approved zinc rich paint.

All high strength bolts, nuts, and washers shall be according to Article 1006.08.

- (2) Tubular. Hollow structural steel tubing shall conform to ASTM A 500 Grade B or ASTM A 501.

After fabrication, the post, base plate, and upper 150 mm (6 in.) of the stud post shall be galvanized according to AASHTO M 111.

All high strength bolts, nuts, and washers shall be according to Article 1006.08.

- (3) Telescoping. The post shall be a square tube formed of 12 gauge steel according to the standard specification for cold rolled carbon steel sheets commercial quality ASTM A 366. The post shall be formed to size and, if necessary, shall be welded in such a manner that weld or flash shall not interfere with telescoping. Holes  $11 \pm 0.4$  mm ( $7/16 \pm 1/64$  in.) will be spaced on 25 mm (1 in.) centers on at least two opposite sides. The holes shall align to accept a 10 mm (3/8 in.) bolt through the post at any location. The post shall have a smooth galvanized finish applied either before or after forming.

The following tolerances will be permitted:

The nominal outside dimension will not vary more than  $\pm 0.2$  mm ( $\pm 0.008$  in.) [ $\pm 2.5$  mm ( $\pm 0.10$  in.) for the 57 mm (2 1/4 in.) size] from the dimension stipulated. The wall thickness will not vary more than + 0.28 mm to -0.20 mm (+ 0.011 in. to -0.008 in.) from the standard 12 gauge plate thickness. The maximum allowable twist in a 1 m (3 ft) length and the permissible variation in squareness shall be as shown in the following table:

<u>Post Size</u>	<u>Squareness</u>	<u>Twist</u>
44 mm x 44 mm	$\pm 0.25$ mm	1.7 mm
51 mm x 51 mm	$\pm 0.30$ mm	1.7 mm
57 mm x 57 mm	$\pm 0.35$ mm	1.7 mm
<u>Post Size</u>	<u>Squareness</u>	<u>Twist</u>
1 3/4 in. x 1 3/4 in.	$\pm 0.010$ in.	0.062 in.
2 in. x 2 in.	$\pm 0.012$ in.	0.062 in.
2 1/4 in. x 2 1/4 in.	$\pm 0.014$ in.	0.062 in.

The posts shall be straight and have a smooth uniform finish. It shall be possible to telescope all consecutive sizes of posts freely and for at least 3.0 m (10 ft) of their length without the necessity of matching any particular face to any other face. All holes and ends shall be free from burrs and ends shall be cut square.

The posts shall be hot-dipped galvanized according to AASHTO M 111, or given triple coated protection by in-line application of hot-dip galvanized zinc per AASHTO M 111 followed by a chromate conversion coating and a cross-linked polyurethane acrylic exterior coating. The inside surfaces shall be given corrosion protection by in-line application of a full zinc base organic coating after fabrication, tested in accordance with ASTM B117. If a weld process is performed after galvanizing, the weld shall be zinc-coated after the scarfing operation.

- (b) Wood. Southern Pine No. 2 or better - Structural Joints and Planks, according to Paragraph 343 of the Southern Pine Inspection Bureau Grading Rules or Douglas Fir No. 2 - Structural Joists and Planks, according to Paragraph 123C of the West Coast Lumber Inspection Bureau Standard Grading Rules shall be used.

The posts shall be nominal 100 mm x 150 mm (4 in. x 6 in.) and rectangular in shape with the lengths of the posts as specified in the plans. The posts shall be surfaced on all four sides (S4S).

Wood signposts shall be pressure treated according to Article 1007.12 except creosote oil shall not be used.

**1093.02 Base for Telescoping Sign Support.** The base shall be cast from iron conforming to ASTM A 126 Class A. The finished casting shall be free from burrs, cracks, voids, or other defects.

After being thoroughly cleaned of all grease, dirt, oil, and loose scale, the casting shall be primed with two coats of paint according to the requirements of Article 1008.19. The exterior shall be finished with two coats of aluminum paint according to the applicable requirements of Articles 506.01 to 506.03, inclusive, and 506.05.

The nominal inside dimension of the square hole shall not vary more than 1.6 mm (1/16 in.) from the dimension shown in the plans.

**1093.03 Concrete Foundation for Wood Posts.** This type of sign support foundation shall be fabricated with Class SI concrete, according to the applicable requirements of Section 734.

The reinforcement bars to be incorporated in this foundation shall be No. 10 (No. 3) and shall be furnished according to the applicable portions of Section 508.

## SECTION 1094. OVERHEAD SIGN STRUCTURES

**1094.01 General.** Materials used in the fabrication of trusses, cantilevers, and bridge-mounted sign structures, including their supports and walkways, shall be according to the specifications set forth in the plans and the following: High Strength Steel Bolts, Nuts and Hardened Washers, Fabric Pads, Stainless Steel Bolts and Screws.

**1094.02 Stainless Steel Nuts.** All stainless steel nuts shall be according to Article 1006.29(d). The nuts shall be "locknuts" with semifinished hexagonal heads equivalent to the finished hex series of the American National Standard.

**1094.03 Anchor Rods, Nuts and Washers.** Anchor rods, nuts and washers shall conform to AASHTO M314 or ASTM F1554 Grades 250 and 380 (Grades 36 and 55) and shall be galvanized according to Article 1006.09.

**1094.04 Conduit.** All conduit furnished shall be 75 mm (3 in.) nominal size and shall comply with ANSI C 80.1 or 80.5. The interior and exterior surfaces of steel conduit shall be galvanized.

**1094.05 Mounting Hardware.** Carbon steel bolts, nuts, and washers shall be according to ASTM A 307, Grade A and either AASHTO M 232, Class D, or ASTM B 633M (B 633) SC3.

All bolts, nuts, and flat washers shall be coated in conformance with one of the following: AASHTO M 232, Class D; ASTM A 164, Grade GS; or ASTM A 165, Grade NS.

**1094.06 Structural Aluminum.** The aluminum alloys to be welded under these specifications may be any of the following ASTM designations:

- (a) Aluminum Fabrication. Aluminum shall be assembled, welded, and inspected according to ANSI/AWS D1.2, "Structural Welding Code-Aluminum", except as herein modified.
- (b) Load-carrying Elements. All primary load carrying elements shall be evaluated as Class I structures by the D 1.2 code.

Wrought nonheat-treatable alloys: Alloy 3003 and Alloy 3004

Wrought heat-treatable alloys: Alloy 6061 and Alloy 6063

Cast heat-treatable alloys: ASTM B 26 or B 108, Alloy A 356-T61, A444-T4, or AASHTO M193.

Material used for permanent backing shall be at least equivalent in weldability to the base metal being welded.

- (c) Welding Processes. These specifications include provisions for welding by the gas metal-arc process and the gas tungsten-arc process. Other processes may not be used, except as permitted by the Engineer.

Tungsten electrodes for the gas tungsten-arc process shall conform to the requirements of the latest edition of Specification for Tungsten-Arc Welding Electrodes, AWS A 5.12.



Filler metals to be used with particular base metals shall be as shown in Table 1. Other filler metals may be used as approved by the Engineer or as specified in the plans.

Table 1

<u>Base Metal</u>	<u>Filler Metal</u>
3003 to 3003	ER1100
3004 to 3004	ER4043
3003 to 6061	ER5183 or 5356
6061 to 6061	ER5356*
6063 to 6063	ER5356*
A356-T61 or A444-T4 to 3003	ER4043 or 4145
A356-T61 or A444-T4 to 6061	ER4043 or 4145
A356-T61 or A444-T4 to 6063	ER4043
A356-T61 to A356-T61	ER4043
A444-T4 to A444-T4	ER4043

\* ER5356 and ER5556 may be used interchangeably for these base metals.

Filler metals shall be kept covered and stored in a dry place at relatively uniform temperatures. Original rod or wire containers shall not be opened until time to be used. Rod and wire shall be free of moisture, lubricant, or other contaminants. Spools of wire temporarily left unused on the welding machine shall be kept covered to avoid contamination by dirt and grease collecting on the wire. If a spool of wire is to be unused for more than a short length of time, it shall be returned to the carton and the carton tightly resealed.

- (d) **Shielding Gases.** Shielding gas for gas metal-arc welding shall be argon, helium, or a mixture of the two (approximately 75 percent helium and 25 percent argon).

Shielding gas for gas tungsten-arc welding done with alternating current shall be argon.

Shielding gas for tungsten-arc welding done with direct current, straight polarity, shall be helium.

Hose used for shielding gases shall be made of synthetic rubber or plastic. Natural rubber hose shall not be used. Hose that has been previously used for acetylene or other gases shall not be used.

- (e) **Preparation of Materials.** Joint details shall be according to design requirements and detail drawings. The locations of joints shall not be changed without the approval of the Engineer.

Edge preparation shall be by sawing, machining, clipping, or shearing. Gas tungsten-arc or gas metal-arc cutting may also be used. Cut surfaces shall meet the American Standards Association's surface roughness rating value of 1,000. Oxygen cutting shall not be used.

Surfaces and edges to be welded shall be free from fins, tears, and other defects that would adversely affect the quality of the weld.

Dirt, grease, forming or machining lubricants, or any organic materials shall be removed from the areas to be welded by cleaning with a suitable solvent or by vapor degreasing.

The oxide shall be removed from all edges and surfaces to be welded just prior to welding by wire brushing or by other mechanical methods, such as rubbing with steel wool or abrasive cloth, scraping, filing, rotary planing, or sanding. If wire brushing is used, the brushes shall be made of stainless steel. Hand or power driven wire brushes and other mechanical devices that have been used on other materials shall not be used on aluminum.

Where mechanical methods of oxide removal are found to be inadequate, a standard chemical method shall be used. Welding shall be done within 24 hours after chemical treatment.

When gas tungsten-arc welding with direct current, straight polarity, is being used, all edges and surfaces to be welded shall have the oxide removed by a standard chemical method.

Welding shall not be done on anodically treated aluminum unless the condition is removed from the joint area to be welded.

- (f) Welding Procedure. All butt welds requiring 100 percent penetration, except those produced with the aid of backing, shall have the root of the initial weld chipped or machined out to sound metal before welding is started from the second side. Butt welds made with the use of backing shall have the weld metal thoroughly fused with the backing. Where accessible, backing for welds that are subject to computed stress or which are exposed to view on the completed structure and which are not otherwise parts of the structure shall be removed and the joints ground or machined smooth. In tubular members, butt welds subjected to computed stresses shall be made with the aid of permanent backing rings or strips.

The procedure used for production welding of any particular joint shall be the same as used in the procedure qualification for the joint.

All welding operations, either shop or field, shall be protected from air currents or drafts so as to prevent any loss of gas shielding during welding. Adequate gas shielding shall be provided to protect the molten metal during solidification.

The work shall be positioned for flat position welding whenever practicable.

In both shop and field, all weld joints shall be dry at time of welding.

The size of the electrode, voltage and amperage, welding speed, gas or gas mixture, and gas flow rate shall be suitable for the thickness of the material, design of joint, welding position, and other circumstances influencing the work, and shall be shown on the approved Weld Procedure Specification (WPS).

Gas metal-arc welding shall be done with direct current, reverse polarity.

Gas tungsten-arc welding shall be done with alternating current or straight polarity direct current.

The Contractor shall submit to the Engineer, at his request, two weld samples for destructive testing and macroetching. These samples shall be welded according to the procedures that will be used in production welding. The Contractor shall submit to the Engineer for approval, the procedure to be used for the test samples and production welding. Should test of these samples indicate unsatisfactory welding, additional samples shall be furnished without cost to the Department. Poor workmanship as noted by visual inspection shall be sufficient cause for rejection.

Where preheat is needed, the temperature of preheat shall not exceed 177 °C (350 °F) for nonheat-treated alloys. The temperature shall be measured by temperature indicating crayons, contact or accurate [ $\pm 2$  °C (3.6 °F)] non-contact pyrometric equipment. Heat-treated alloys shall not be held at or near the maximum preheat temperature for more than 35 minutes.

- (g) Welding Quality. Regardless of the method of inspection, the acceptance or rejection of welds shall comply with the D 1.2 Code and the following conditions:

Welds having defects exceeding the levels of acceptance specified shall be considered as rejected unless corrected according to Article 1094.06(i).

Undercut shall not be more than 0.25 mm (0.01 in.) deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than 0.80 mm (1/32 in.) deep when its direction is parallel to the primary stress in the part that is undercut. When undercut is present, the affected area shall be ground to a smooth transition.

- (h) Nondestructive Examination/Nondestructive Testing (NDE/NDT). To determine compliance with these specifications, all welds shall be visually inspected and, in addition, complete joint penetration welds subjected to computed stress shall be inspected by radiographic testing (RT) for butt welds and ultrasonic testing (UT) for T and corner joints. RT shall utilize aluminum edge blocks and location marks similar to those specified for steel in Article 505.04 in addition to the D1.2 requirements.

The dye penetrant testing (DPT) shall be performed according to ASTM E 165, Standard Methods for Liquid Penetrant Inspection, Method B, Procedure B-2 or B-3. PT shall be used on partial joint penetration and fillet welds as follows:

100 percent of the top and bottom cantilever truss chords to connection and gusset plates near column; 25 percent of top connection plate to collar; 100 percent of simple span splice flanges to main chords, and random 10 percent of main chords to diagonals, horizontals, and verticals as directed by the Engineer.

Dye penetrant inspection may be omitted, provided the inspector examines each layer of weld metal with a magnifier of 3X minimum before the next successive layer is deposited.

Required NDE/NDT shall be the responsibility of the Contractor and its cost shall be included in the fabrication.

- (i) Corrections. In lieu of rejection of an entire member containing welding that is unacceptable, the corrective measures may be permitted by the Engineer, if the extent of repairs will not adversely effect the structure's serviceability.

Defective welds shall be corrected by removing and replacing the entire weld or as permitted by D1.2 Code. Copper or tungsten inclusions shall be completely removed.

Before rewelding, the joint shall be inspected to assure all of the defective weld has been removed. If dye penetrant has been used to inspect the weld, all traces of penetrant solutions shall be removed with solvent, water, heat, or other suitable means before rewelding.

Repaired areas shall be 100 percent inspected by RT, UT or PT as applicable.

- (j) Qualification of Procedures, Welders, and Welding Operators. Joint welding procedures that are to be employed under these specifications shall be qualified by tests prescribed in the D1.2 Code. The qualifications shall be at the expense of the Contractor. The Engineer may accept properly documented evidence of previous qualification of the joint welding procedures to be employed.

All welders and welding operators shall be qualified by tests specified by the D1.2 Code. The Engineer may accept properly documented evidence of previous qualification of the welders and welding operators to be employed.

**1094.07 Structural Steel.** All structural steel pipe shall be ASTM A-53 Grade B with a minimum yield of 240,000 kPa (35 ksi) or A 500 Grade B or C with a minimum yield of 317,000 kPa (46 ksi). All structural steel plates and shapes shall be according to AASHTO M 270M, Grades 250, 345, or 345W (M 270, Grades, 36, 50, or 50 W), M 183M (M 183), M 223M, Grade 345 (M 223 Grade 50) or M 222M (M 222). Stainless steel for shims and handhole covers shall be ASTM A 240, Type 302

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or 304, or another alloy suitable for exterior exposure and acceptable to the Engineer. Steel to be hot dip galvanized shall have a silicon content either less than 0.04 percent or between 0.15 percent and 0.25 percent.

## SECTION 1095. PAVEMENT MARKINGS

**1095.01 Thermoplastic Pavement Markings.** This material shall be a mixture of resins and other materials providing an essentially nonvolatile thermoplastic compound especially developed for traffic markings.

(a) Ingredient Materials:

- (1) Binder. The binder shall consist of a mixture of synthetic resins, at least one of which is solid at room temperature. The solid resin shall be a hydrocarbon or alkyd resin. The total binder content of the thermoplastic compound shall be well distributed throughout the compound. The binder shall be free from all foreign objects or ingredients that would cause bleeding, staining, or discoloration. The binder shall be 18 percent minimum by weight of the thermoplastic compound. The binder shall be characterized by an IR Spectra. Future shipments of binder will be checked by an IR Spectra to verify that the binder has not been changed.

- (2) Pigment. The pigment used for the white thermoplastic compound shall be a high-grade pure (minimum 93 percent) titanium dioxide ( $\text{TiO}_2$ ). The white pigment content shall not be less than ten percent by weight and shall be uniformly distributed throughout the thermoplastic compound.

The pigments used for the yellow thermoplastic compound shall be nontoxic, heat resistant, and color-fast yellows, golds, and oranges, which shall produce a compound meeting the requirements of the current Federal Highway Color Tolerance Chart, PR Color No. 1. The medium chrome yellow pigment content shall be not less than four percent by weight and shall be uniformly distributed throughout the thermoplastic compound.

- (3) Filler. The filler to be incorporated with the resins as a binder shall be a white calcium carbonate, silica, or an approved substitute. Any filler which is insoluble in 6N hydrochloric acid shall be of such particle size as to pass a 150  $\mu\text{m}$  (No. 100) sieve.
- (4) Glass Beads. The intermix glass beads shall be according to Article 1095.07 Type A.

(b) Thermoplastic Compound:

- (1) Characteristic Requirements.

- a. In the plastic state, the material shall not give off fumes that are toxic or otherwise injurious to persons or property. The manufacturer shall provide material safety data sheets for the product.
- b. The temperature versus viscosity characteristic of the plastic material shall remain constant and the material shall not deteriorate in any manner during reheating processes.
- c. There shall be no obvious change in color of the material as a result of repeated heatings or from batch to batch. The maximum elapsed time after application after which normal traffic will leave no impression or imprint on the new stripe shall be two minutes at 10 °C (50 °F) or five minutes at 32 °C (90 °F) pavement temperature. After application and proper drying, the material shall show no appreciable deformation or discoloration, shall remain free from tack, and shall not lift from the pavement under normal traffic conditions within a road temperature range of -29 to 66 °C (-20 to 150 °F). The stripe shall maintain its original color, dimensions and placement.

Cold ductility of the material shall be such as to permit normal dimensional distortion as a result of traffic impact within the temperature range specified.

- d. The material shall provide a stripe that has a uniform color and thickness throughout its cross section and has the density and character to provide a sharp edge of the line.
- e. Daylight Reflectance and Color. The thermoplastic compound after heating for four hours ± five minutes at 218.3 ± 2 °C (425 ± 3 °F) and cooled at 25 °C (77 °F) shall meet the following requirements for daylight reflectance and color, when tested, using a color spectrophotometer with 45 degree circumferential/zero degree geometry, illuminant C, and two degree observer angle. The color instrument shall measure the visible spectrum from 380 to 720 nm with a wavelength measurement interval and spectral bandpass of 10 nm.

White: Daylight Reflectance ...75 percent min  
\*Yellow: Daylight Reflectance ...45 percent min

\*Shall match Federal Highway Color Tolerance Chart, PR Color No. 1

- f. Specific Gravity. After heating the thermoplastic for four hours ± five minutes at 218.3 ± 2 °C (425 ± 3 °F), the specific gravity of the thermoplastic material shall be from 1.8 to 2.4 when determined according to ASTM D 153, Method A, using kerosene as the immersion liquid.

- g. Water Absorption of Plastics. The material shall have not more than 0.5 percent by weight of retained water when tested by ASTM D 570, "Water Absorption of Plastics," Procedure (a).
  - h. Softening Point. After heating the thermoplastic material for four hours  $\pm$  five minutes at  $218.3 \pm 2$  °C ( $425 \pm 3$  °F) and testing in accordance with ASTM E 28, the material shall have a softening point between  $93.3 - 115.6$  °C ( $200 - 240$  °F) as measured by the ring and ball method.
  - i. Tensile Bond Strength. After heating the thermoplastic material for four hours  $\pm$  five minutes at  $218.3 \pm 2$  °C ( $425 \pm 3$  °F), the tensile bond strength to unprimed, sandblasted portland cement concrete block, 1.587 mm (0.0625 in.) thick film drawn down at  $218.3$  °C ( $425$  °F), tested at  $23.9 \pm 1$  °C ( $75 \pm 2$  °F) shall exceed 1,030 kPa (150 psi) when tested in accordance with ASTM D 4796.
  - j. Yellowness Index. After heating the thermoplastic for four hours  $\pm$  five minutes at  $218.3 \pm 2$  °C ( $425 \pm 3$  °F), the white thermoplastic material shall not exceed a yellowness index of 12 when tested in accordance with ASTM D 1925.
- (2) Packaging. The thermoplastic material shall be packaged in suitable containers which will not adhere to the product during shipment and storage. The container of thermoplastic material shall weigh approximately 22.7 kg (50 lb), and shall be delivered on pallets, 40 containers per pallet. The lot size shall be approximately 20,000 kg (44,000 pounds) unless the total order is less than that amount.

Each container of material shall be stenciled with the manufacturer's name, the type of material (alkyd or hydrocarbon), color of material (white or yellow), IDOT specification number (1095.01), the month and year the material was packaged and the lot number. Lot numbers must begin with the last two digits of the year manufactured and be sequential with lot 1; i.e., the first lot manufactured in 1997 should be labeled 97-1. The letters and numbers used in the stencils shall be a minimum of 12.7 mm (1/2 in.) in height.

- (3) Storage Life. The material shall maintain a granular free-flow condition in dry storage for a minimum of one year, providing the temperature does not exceed 40 °C (104 °F). The thermoplastic must also melt uniformly with no evidence of skins or unmelted particles and meet all requirements of this specification for one year after delivery. Any material not meeting the above requirements shall be disposed of by the vendor and immediately replaced with acceptable material entirely at his expense, including handling and transportation charges.

(c) Sampling and Inspection:

- (1) The manufacturer shall forward preliminary samples of thermoplastic and ingredient materials to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois, 62704-4766 for testing. The thermoplastic and ingredient materials shall be representative of the materials used/made and may not be changed without approval of the Department. All samples shall be provided in friction-top metal containers in the quantities specified. (Approximately 30 days are required to complete testing of the qualification samples.)

a. Ingredient Materials.

1. Glass beads. 1 L (1 qt).
2. Binder. 0.5 L (1 pt).
3. Pigments. 0.5 L (1 pt).
4. Filler. 0.5 L (1 pt).

b. Thermoplastic. 4 L (1 gal).

- (2) Sampling and Testing. Unless otherwise provided, all materials shall be sampled and tested in accordance with the latest published standard methods of the American Society for Testing and Materials, and revisions thereof, in effect on the date of the invitation for bids, where such standard methods exist. In case there are no ASTM Standards which apply, applicable standard methods of the American Association of State Highway and Transportation Officials, or the Federal Government, or of other recognized standardizing agencies shall be used. The sample(s) shall be labeled with the shipment number if applicable, lot number, date, quantity and any other pertinent information.

Thermoplastic. At least three randomly selected containers shall be obtained from each lot. A 4 L (1 gal) composite sample of the three containers shall be submitted for testing and acceptance.

- (3) Inspection. All material samples for acceptance tests shall be taken or witnessed by a representative of the Bureau of Materials and Physical Research and shall be submitted to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766 at least 30 days in advance of the pavement marking operations. The right is reserved to inspect the material either at the place of manufacture or at the destination or at both places. If inspected at the place of manufacture, the manufacturer



shall furnish such facilities as may be required for collecting and forwarding samples, and shall also furnish facilities for testing the material during the process of manufacture, if required. Tests will be made by and at the expense of the Department. Random check samples may be taken at the job site at the discretion of the Engineer.

(d) Manufacturer's Responsibility:

- (1) The manufacturer shall perform tests on a minimum of one sample per 4,500 kg (10,000 lb) of thermoplastic produced. Minimum tests required shall be a softening point determination and color. Manufacturer's test results shall be submitted along with the thermoplastic sample to the Bureau of Materials and Physical Research.
- (2) The manufacturer shall retain the test sample for a minimum period of 18 months.
- (3) The manufacturer shall furnish the Bureau of Materials and Physical Research with copies of bills of lading for all material inspected. Bills of lading shall indicate the consignee and destination, date of shipment, lot numbers, quantity, type of material, name and location of source.

(e) Material Acceptance. Final acceptance of a particular lot of thermoplastic will be based on the following:

- (1) Compliance of ingredient materials with the specifications.
  - (2) Compliance of thermoplastic material with the specifications.
  - (3) Manufacturer's test results for each lot of thermoplastic have been received.
  - (4) Identification requirements are satisfactory.
- (f) Glass Beads. The glass beads used as drop on beads with the thermoplastic pavement marking material shall meet the requirements of Article 1095.07 Type B. The beads shall be applied uniformly at a minimum rate of 39 kg/100 sq m (8 lb/100 sq ft).

**1095.02 Paint Pavement Markings.** All materials shall meet the following paint specification unless a shortage of raw materials precludes the production of paint which will meet the materials portion of this section. If the shortage can be documented to the satisfaction of the Engineer, then an alternate formulation will be allowed. Any alternate formulation must comply with the Bureau of Materials specification M-123 or the latest acceptable alternate to this specification. Copies of these specifications may be obtained from the Engineer of Materials and Physical Research..

The finished paint shall be formulated and manufactured from first-grade materials. It shall be free from defects and imperfections that might adversely affect the serviceability of the finished product. It shall be completely free from dirt and other foreign material and shall dry within the time specified to a good, tough, serviceable film. The paint shall show no evidence of excessive settling, gelling, skinning, spoilage or living upon storage in the sealed shipping containers under normal above freezing temperatures within twelve months of delivery. Any settled portion shall be easily brought back into suspension by hand mixing. When the settled portion is brought back into suspension in the vehicle, the paint shall be homogeneous and shall not show a viscosity change of more than 5 KU from the original viscosity. Any paint that has settled within the period of twelve months after delivery to the degree that the settled portion cannot be easily brought into suspension by hand mixing shall be disposed of by the vendor and immediately replaced with acceptable material entirely at his expense, including handling and transportation charges. The paint, when applied by spraying methods to a bituminous pavement, shall not be discolored due to the solvent action of the paint on the bituminous surface.

(a) Ingredient Materials.

- (1) Titanium Dioxide. This material shall comply with the latest revision of the Specification for Titanium Dioxide Pigments, ASTM D 476, Type II, Rutile. A notarized certificate of compliance from the pigment manufacturer shall be required.
- (2) Yellow Pigment. This material shall be a non-toxic organic pigment, Yellow 65: Engelhard 1244 or equivalent.
- (3) Calcium Carbonate. This material shall comply with the latest revision of the Specification for Calcium Carbonate Pigments, ASTM D 1199, Type GC, Grade I, with minimum of 95 percent Calcium Carbonate or Type PC, minimum 98 percent Calcium Carbonate.
- (4) Acrylic Emulsion Polymer. This material shall be Rohm and Haas 2706 or Dow Chemical DT-211.
- (5) Methyl Alcohol. This material shall comply with the latest revision of the Specification for Methyl Alcohol, ASTM D 1152.
- (6) Miscellaneous Materials.
  - a. Water: Potable
  - b. Dispersant: Tamol 850 (Rohm and Haas) or equivalent
  - c. Surfactant: Triton CF-10 (Union Carbide) or equivalent
  - d. Defoamer: Colloids 654 (Rhône-Poulenc) or equivalent
  - e. Rheology Modifier: Natrasol 250 HBR (Aqualon Company) or equivalent

f. Coalescent: Texanol (Eastman Chemical)

g. Preservative: Troy 192 (Troy Chemical) or equivalent

- (b) Manufacture. All ingredient materials shall be delivered in the original containers and shall be used without adulteration. The containers shall be marked with type of material, name of manufacturer and lot number.

The manufacturer shall furnish to the Department the batch formula which will be used in manufacturing the paint.

No change shall be made in this formula without prior approval by the Department and no change will be approved that adversely affects the quality or serviceability of the paint.

The following Standard Formulas shall be the basis for the paint. The finished products shall conform on a weight basis to the composition requirements of these formulas. No variations will be permitted except for the replacement of volatile lost in processing. Amounts are shown in kilograms (pounds) of material.

	White	Yellow
C.I. Pigment Yellow 65	---	14.52 (32)
Titanium Dioxide, Rutile, Type II	45.36 (100)	9.53 (21)
Calcium Carbonate, Type PC	68.04 (150)	68.04 (150)
Calcium Carbonate, Type GC	195.05 (430)	210.92 (465)
Rheology Modifier	0.23 (0.5)	0.23 (0.5)
Acrylic Emulsion, 50% Solids	245.40 (541)	242.68 (535)
Coalescent	10.89 (24)	10.43 (23)
Defoamer	2.27 (5)	2.27 (5)
Dispersant	3.63 (8)	4.08 (9)
Surfactant	0.91 (2)	0.91 (2)
Methyl Alcohol	13.15 (29)	12.70 (28)
Preservative	0.68 (1.5)	0.68 (1.5)
Water	4.54 (10)	4.54 (10)
Total Kilograms	590.15 (1301)	581.53 (1282)

- (c) Paint Properties. The finished paint shall meet the following requirements:

- (1) Pigment. Analysis of the extracted pigment shall conform to the following requirements:

	White	Yellow
Organic Yellow 65 (%)	---	Min 4.8
Titanium Dioxide (%)	Min 13.4	Min 2.8
Calcium Carbonate (%)	Max. 86	Max. 93

The percent pigment by weight of the finished product shall not be less than 50 percent nor more than 54 percent.

- (2) Vehicle. The non-volatile portion of the vehicle shall be composed of a 100 percent acrylic polymer and shall not be less than 44 percent by weight.
- (3) Organic Volatiles. The finished paint shall contain less than 150 grams of volatile organic matter per liter of total paint. (ASTM D3960)
- (4) Total Solids. The finished paint shall not be less than 73 percent total non-volatile by weight. (ASTM D2369)
- (5) Unit Weight. The unit weight at 25 °C (77 °F) of the production batches shall not vary more than plus or minus 0.024 kg/L (0.20 lb/gal) from the weight of the qualification samples.
- (6) Viscosity. The consistency of the paint shall not be less than 83 nor more than 98 Kreb units at 25 °C (77 °F).
- (7) Dry Opacity. The minimum contrast ratio shall be 0.97 when tested in accordance with Federal Specification, Method 141 a, No. 4121, Procedure B when applied at a wet film thickness of 0.38 mm (15 mils).
- (8) Color And Directional Reflectance. The paint, applied at a wet film thickness of 0.38 mm (15 mils) and allowed to dry 24 hours, shall meet the following requirements for daylight reflectance and color, when tested, using a color spectrophotometer with 45 degrees circumferential/zero degree geometry, illuminant C, and two degree observer angle. The color instrument shall measure the visible spectrum from 380 to 720 nm with a wavelength measurement interval and spectral bandpass of 10 nm.

White: Daylight Reflectance (Y) 85 percent minimum  
Yellow:\* Daylight Reflectance (Y) 50 percent minimum

\*Shall match Federal 595 Color No. 33538 and chromaticity limits as follows:

x	0.490	0.475	0.485	0.530
y	0.470	0.438	0.425	0.456

- (9) Water Resistance. The paint shall conform to Federal Specification TT-P-1952D, Section 3.2.5.
- (10) Freeze-Thaw Stability. The paint shall show no coagulation or change in consistency greater than 10 Kreb Units, when tested in accordance with Federal Specification TT-P-1952D, Section 4.3.8.
- (11) Accelerated Package Stability. The paint shall show no coagulation, discoloration, or change in consistency greater than 10 Kreb Units when tested in accordance with Federal Specification TT-P-1952D, Section 4.3.4.

- (12) Dilution Test. The paint shall be capable of dilution with water at all levels without curdling or precipitation such that the wet paint can be readily cleaned up with water only.
  - (13) Storage Stability. After 30 days storage in a three-quarters filled, closed container, the paint shall show no caking that cannot be readily remixed to a smooth, homogenous state, no skinning, livering, curdling or hard settling. The viscosity shall not change more than 5 Kneb units from the viscosity of the original sample.
  - (14) No Pick-Up Time. The no pick-up time shall be less than 10 minutes. The test shall follow the requirements of ASTM D 711 with a wet film thickness of 0.38 mm (15 mils).
  - (15) Grind. The paint shall have a grind of not less than 3 on a Hegman Grind Gauge.
  - (16) Flexibility. The paint shall show no cracking or flaking when tested in accordance with Federal Specification TT-P-1952D, Section 4.3.5.
  - (17) Dry Through Time. The paint, when applied to a non-absorbent substrate at a wet film thickness of 0.38 mm (15 mils) and placed in a humidity chamber controlled at  $90 \pm 5$  percent R.H. and  $22.5 \pm 1.4$  °C ( $72.5 \pm 2.5$  °F) shall have a "dry through time" not greater than 15 minutes of the IDOT standard formula. The dry through time shall be determined according to ASTM D1640, except that the pressure exerted shall be the minimum needed to maintain contact with the thumb and film.
  - (18) No-Tracking Time Field Test. The paint shall dry to a no-tracking condition under traffic in three minutes maximum when applied at  $0.38 \pm 0.03$  mm ( $15 \pm 1$  mil) wet film thickness at  $54.4 - 65.6$  °C ( $130 - 150$  °F), and from three to ten minutes when applied at ambient temperatures with 0.72 kg (6 lb) of glass beads per liter (gallon) of paint. "No-tracking" shall be the time in minutes required for the line to withstand the running of a standard automobile over the line at a speed of approximately 65 km/hour (40 mph), simulating a passing procedure without tracking of the reflectorized line when viewed from a distance of 15 m (50 ft).
- (d) Sampling and Inspection.
- (1) Sample. The manufacturer shall forward to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766, for test purposes, three 1/2 L (1 pt) qualification samples of material representative of that which he/she proposes to produce.

Along with the samples, the paint manufacturer shall furnish a copy of his/her batching formula and a list of the trade names and manufacturers of the ingredient materials proposed for use. Product data sheets shall be provided as verification of the ingredient materials conformity with the

specification requirements. No changes shall be made without prior approval by the Department.

- (2) Sampling and Testing. Unless otherwise provided, all materials shall be sampled and tested in accordance with the latest published standard methods of the American Society for Testing and Materials, and revisions thereof, in effect on the date of manufacture, where such standard methods exist. In case there are no ASTM Standards which apply, applicable standard methods of the American Association of State Highway and Transportation Officials, or of the Federal Government, or of other recognized standardizing agencies shall be used.
- (3) Inspection. The right is reserved to inspect the paint either at the place of manufacture or after its arrival at destination. If inspected at the place of manufacture, the manufacturer shall furnish such facilities as may be required for collecting and forwarding samples of ingredient materials and finished paint and for performing the inspection of the paint during the process of manufacture. Before manufacture of the paint is started, the ingredient materials shall be set aside at the manufacturer's plant and shall be sampled by an authorized representative of the Department. All materials represented by these samples shall be held until tests have been made and the materials found to comply with the requirements of the specifications. Approximately 30 days are required to test the ingredient materials. The Department has the option to waive inspection of ingredient materials. During the manufacturing operations, the Department's representative shall have free entry at all times to such parts of the plant as concern the manufacture of the paint. All tests will be made by and at the expense of the Department.

All material samples for acceptance tests shall be taken or witnessed by a representative of the Bureau of Materials and Physical Research and shall be submitted to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766.

- (e) Packaging. Unless otherwise directed, the paint shall be packaged and shipped in new 55 gal removable head, steel drums meeting the latest regulations of the United States Department of Transportation for shipping containers for this type of material. The drums shall be lined with a non-corrosive lining compatible with the waterborne paint. The opening in the drum shall be circular, and the diameter of the opening shall be substantially the diameter of the inside of the end of the drum. The drum shall be provided with gaskets of one-piece tubular neoprene construction and shall be completely airtight. The closure shall be securely attached to the drum by a bolt-action-type ring that shall enclose the edge of the lid and the chime of the drum. The closure bolt shall be tightened to a minimum of 54 N m (40 ft lb) torque, and a lock nut shall be securely tightened against the threaded end of the anchor. The white paint shall be packaged in white drums with white lids, and the yellow paint shall be packaged in white drums with yellow lids.

Fifty-five gallons of paint shall be placed in each drum, leaving approximately 5 cm (2 in.) of air space. The paint will be measured by volume, the unit of measure being a gallon [231 cu in. at 25 °C (77 °F)].

Each drum shall be stenciled on the removable head and on the side to show the kind of paint contained therein, the manufacturer's name, the lot number, and the month and year the paint is packaged.

- (f) Glass Beads. The glass beads used as drop on beads with the pavement marking paint shall conform to the requirements of Article 1095.07 Type B.

**1095.03 Preformed Plastic Pavement Markings.** The material shall consist of white or yellow (as specified) weather resistant reflective film conforming to the requirements specified herein.

- (a) Composition. The preformed plastic marking shall consist of high- quality plastic materials, pigments, and glass beads and shall be furnished with a pressure sensitive precoated adhesive.

The markings shall have the following minimum composition without adhesive:

<u>Components</u>	<u>Minimum Percent By Weight</u>
Resins and Plasticizers	20%
Pigment and Fillers	30%
Graded Glass Beads	25%

The remaining percentage shall be comprised of the above materials in various proportions.

- (b) Conformability and Resealing. The marking shall conform to pavement contours, breaks, faults, etc. through the action of traffic at all pavement temperatures. The film shall have resealing characteristics and shall be capable of fusing with itself or with previously applied marking material.
- (c) Thickness. Prior to application, the thickness of the material, without adhesive, shall be at least 1.50 mm (60 mils).

The Type B material shall feature and embossed pattern with a minimum thickness of 1.65 mm (65 mils) measured at the thickest point of the patterned cross section and a minimum of 0.508 mm (20 mils) measured at the thinnest point of the cross section.

- (d) Durability and Wear Resistance. The markings, when properly applied, shall provide a neat, durable marking that will not flow or distort due to temperature if the pavement surface remains stable. The markings shall provide a cushioned resilient substrate that reduces bead crushing and loss. The markings shall be weather resistant and, through normal traffic wear, show no appreciable fading, lifting, tearing, rollback, or other signs of poor adhesion.

- (e) Skid Resistance. The surface of the markings shall provide the following minimum skid resistance values when tested according to ASTM E 303:

Type A	35 BPN
Type B	45 BPN
Type C	55 BPN

- (f) Tensile Strength. The material shall have the following minimum tensile strength of cross section when tested according to ASTM D638-76 using a jaw speed of 250 to 300 mm (10 to 12 in.)/minute:

Type A	275 kPa (40 psi)
Type B	Not Applicable
Type C	1033 kPa (150 psi)

- (g) Elongation. The material shall have the following minimum elongation when tested according to ASTM D638-76 using a jaw speed of 250 to 300 mm (10 to 12 in.)/minute.

Type A	15%
Type B	Not Applicable
Type C	50%

- (h) Glass Beads. Glass beads shall be uniformly distributed throughout the markings. A top coating of beads shall be bonded to or directly embedded into the surface of the markings in order to produce immediate retroreflectivity.

The glass beads shall be colorless and have a minimum index of refraction of 1.50 when tested using the liquid immersion method.

Type B material shall have an innermix of glass beads with a minimum index of refraction of 1.50 and a top coating of ceramic beads bonded to top urethane wear surface with a minimum index of refraction of 1.70. Beads with an index of refraction greater than 1.80 shall not be used.

Type C material shall have a layer of skid resistant ceramic particles bonded to the top urethane wear surface. The urethane wear surface shall have a nominal thickness of 0.13 mm (5 mils).

The bead adhesion shall be such that beads are not easily removed when the film is scratched firmly with a thumb nail.

- (i) Plastic Pull Test. A test specimen of 25 mm x 75 mm (1 in. x 3 in.) shall support a dead weight of 1.8 kg (4 lb) for not less than five minutes at a temperature between 21 and 27 °C (70 and 80 °F).
- (j) Pigmentation. The pigment for the white preformed plastic compound shall be a high grade pure (minimum 89 percent) titanium dioxide (TiO<sub>2</sub>). The



white pigment content shall not be less than ten percent by weight and shall be uniformly distributed throughout the compound.

The pigment used for the yellow preformed plastic compound shall be colorfast yellows, golds, and oranges. The yellow pigment content shall not be less than three percent by weight and shall be uniformly distributed throughout the compound.

- (k) Color. The material shall meet the following requirements for daylight reflectance and color, when tested, using a standard color difference meter (0 degrees, 45 degrees) and a magnesium oxide standard or an approved secondary standard.

Types A & B

White:	Daylight reflectance,	65 percent min.
*Yellow:	Daylight reflectance,	45 percent min.

Type C

White:	Daylight reflectance,	Y 80% min.
*Yellow:	Daylight reflectance,	36 yo 59% min.

\*Shall match Federal Highway Color Tolerance Chart, PR Color No. 1 December 1972.

- (l) Reflectance. The white and yellow films shall have the following initial minimum reflectance values at 0.2 degrees and 0.5 degrees observation angles and 86.0 degrees entrance angle as measured according to the testing procedures of Federal Test Method Standard 370. The photometric quantity to be measured shall be Specific Luminance (SL), and shall be expressed as millicandelas/lux/sq m (millicandelas/footcandle/sq ft). The test distance shall be 15 m (50 ft.) and the sample size shall be a 300 mm x 600 mm (1.0 ft x 2.0 ft) rectangle. The angular aperture of both the photoreceptor and light projector shall be six minutes of arc. The reference center shall be the geometric center of the sample, and the reference axis shall be taken perpendicular to the test sample.

Type A

	<u>White</u>		<u>Yellow</u>	
Observation Angle	0.2 degrees	0.5 degrees	0.2 degrees	0.5 degrees
Specific Luminance	550	380	410	250

Type C

	<u>White</u>		<u>Yellow</u>	
Observation Angle	0.2 degrees	0.5 degrees	0.2 degrees	0.5 degrees
Specific Luminance	700	500	410	250

Type B

	<u>White</u>	<u>Yellow</u>
Entrance Angle	86.5 degrees	86.5 degrees
Observation Angle	1.0 degree	1.0 degree
Specific Luminance	700	500

- (m) Identification. The material delivered to the jobsite shall be identified by the same shipment number(s), if applicable, batch or lot number(s), as the sample(s) tested and approved for that job. The batch or lot number(s) of the material, and the month and year the material is packaged, shall be stenciled or embossed on the container or included on the label.
- (n) Sampling and Testing. All material samples for acceptance tests will be taken or witnessed by a representative of the Bureau of Materials and Physical Research and will be submitted to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766. Random check samples may be taken at the jobsite at the discretion of the Engineer.

The Engineer will test and certify the basic requirements.

The Contractor shall provide the Engineer certification from the manufacturer that the material to be furnished meets all the requirements of these specifications.

Sample(s) of preformed plastic shall be a minimum of 0.2 sq m (2 sq ft) of each color to be used.

The sample(s) shall be labeled with the shipment number(s), if applicable, batch or lot number(s), all batch number(s) comprising a lot, date, quantity, and any other pertinent information.

**1095.04 Epoxy Pavement Marking.** All materials shall meet the following specifications:

- (a) The epoxy marking material shall consist of a 100 percent solid two part system formulated and designed to provide a simple volumetric mixing ratio of two components (must be two volumes of Part A and one volume of Part B). No volatile solvents or fillers will be allowed.
- (b) The Epoxide Value (WPE) of Component A shall be 200-300 when tested according to ASTM D-1652 on a pigment free basis.
- (c) The Total Amine Value of Component B shall be 325-475 when tested according to ASTM D-2074.

## (d) Composition by Weight of Component A:

<u>Pigment*</u>	<u>White</u>	<u>Yellow</u>
Titanium Dioxide ASTM D-476 Type II	21-24%	
Chrome Yellow ASTM D-211 Type III		23-26%
Epoxy Resin	76-79%	74-77%

\*No extender pigments are permitted.

- (e) Upon heating to application temperature, the material shall not exude fumes which are toxic or injurious to persons or property.
- (f) The daylight directional reflectance of the cured epoxy (without glass spheres) shall not be less than 80 percent (white) and 50 percent (yellow) relative to magnesium oxide when tested using a color spectrophotometer with a 45 degrees circumferential /zero degrees geometry, illuminant C, and two degrees observer angle. The color instrument shall measure the visible spectrum from 380 to 720 nm with a wavelength measurement interval and spectral bandpass of 10 nm. In addition, the color of the yellow epoxy shall visually match Color Number 33538 of Federal Standard 595a to the satisfaction of the Department.
- (g) The epoxy pavement marking material, when mixed in the proper ratio and applied at 0.35 mm to 0.41 mm (14 to 16 mils) wet film thickness and with the proper saturation of glass spheres, shall exhibit no tracking time of twenty minutes or more when tested according to ASTM D-711.
- (h) The catalyzed epoxy pavement marking materials when applied to a 100 mm x 100 mm x 50 mm (4 in. x 4 in. x 2 in.) concrete block, shall have a degree of adhesion which results in a 100 percent concrete failure in the performance of this test.

The concrete block shall be brushed on one side and have a minimum strength of 24,100 kPa (3500 psi). A 50 mm (2 in.) square film of the mixed epoxy shall be applied to the brushed surface and allowed to cure for 72 hours at room temperature. A 50 mm (2 in.) square cube is then affixed to the surface of the epoxy by means of an epoxy by means of an epoxy glue. After the glue has cured for 24 hours, the epoxy specimen is placed on a dynamic testing machine in such a fashion so that the specimen block is in a fixed position and the 50 mm (2 in.) cube (glued to the epoxy surface) is attached to the dynamometer head. Slowly apply direct upward pressure until the epoxy system fails. Record the location of the break and the amount of concrete failure.

- (i) The epoxy pavement marking materials when tested according to ASTM D2240, shall have a shore D hardness of between 75 and 100. Films shall be cast on a rigid substrate at 0.35 mm to 0.41 mm (14 to 16 mils) in thickness and allowed to cure at room temperature for 72 hours before testing.

- (j) The abrasion resistance shall be evaluated on a Taber Abrader with a 1,000 gram load and CS 17 wheels. The duration of test shall be 1,000 cycles. The loss shall be calculated by difference and be less than 82 mgs. The tests shall be run on cured samples of material which have been applied at a film thickness of 0.35 mm to 0.41 mm (14 to 16 mils) to code S-16 stainless steel plates. The films shall be allowed to cure at room temperature for at least 72 hours before testing.
- (k) When tested according to ASTM D638, the epoxy pavement marking materials shall have a tensile strength of not less than 41,300 kPa (6,000 psi). The Type IV specimens shall be cast in a suitable mold not more than 6.3 mm (1/4 in.) thick and pulled at a rate of 6.3 mm (1/4 in.)/minute by a suitable dynamic testing machine. The samples shall be allowed to cure at room temperature for at least 72 hours before testing.
- (l) When tested according to ASTM 695, the catalyzed epoxy pavement marking materials shall have a compressive strength of not less than 83,000 kPa (12,000 psi). The cast sample shall be conditioned at room temperature for a minimum of 72 hours before performing the indicated tests. The rate of compression of these samples shall 6.3 mm (1/4 in.)/minute or less.
- (m) The glass beads shall meet the requirements of Article 1095.07 and the following requirements:

(1) The first drop glass beads shall meet the following sieve requirements:

<u>Sieve Size</u>	<u>U.S. Standard Sieve Number</u>	<u>% Passing (By Weight)</u>
1.70 mm	12	95-100
1.40 mm	14	75-95
1.18 mm	16	10-47
1.00 mm	18	0-7
850 µm	20	0-5

(2) The second drop glass beads shall meet the requirements of Article 1095.07 Type A.

(3) The glass beads shall have a silane coating.

- (n) The epoxy paint shall be applied to an aluminum alloy panel (Federal Test Std. No. 141, Method 2013) at a film thickness of 0.35 mm to 0.41 mm (14 to 16 mils) and allowed to cure for 72 hours at room temperature. Subject the coated panel for 75 hours to accelerated weathering using the light and water exposure apparatus (fluorescent UV - condensation type) as specified in ASTM G53.

The cycle shall consist of four hours UV exposure at 50 °C (122 °F) followed by four hours of condensation at 40 °C (104 °F). At the end of the exposure period, the panel shall show no substantial change in color or gloss.

- (o) The material shall be shipped to the jobsite in substantial containers and shall be plainly marked with the manufacturer's name and address, the name and color of the material, date of manufacture, and batch number.
- (p) Prior to approval and use of the epoxy pavement marking materials, the manufacturer shall submit a notarized certification from an independent laboratory, together with the results of all tests, stating these materials meet the requirements as set forth herein. The certified test report shall state the lot tested, manufacturer's name, brand name of epoxy and date of manufacture. The certification shall be accompanied by 1/2 liter (1 pt) samples each of Part A and Part B. After approval by the Department, certification by the epoxy manufacturer shall be submitted for each batch used. New independent laboratory certified test results and samples for testing by the Department shall be submitted any time the manufacturing process or paint formulation is changed. All costs of testing (other than tests conducted by the Department) shall be borne by the Manufacturer.
- (q) Acceptance samples, shall consist of two 1/2 L (1 pt) samples of Part A and one 1/2 L (1 pt) sample of Part B, of each lot of paint. The samples shall be submitted to the Department for testing, together with a manufacturer's certification. The certification shall state the formulation for the lot represented is essentially identical to that used for qualification testing. All acceptance samples shall be taken by a representative of the Illinois Department of Transportation. The epoxy pavement marking materials shall not be used until tests are completed and they have met the requirements as set forth herein.

**1095.05 Preformed Thermoplastic Pavement Marking.** All materials shall meet the requirements of Article 1095.01 and the following specifications:

- (a) The preformed thermoplastic pavement marking film shall consist of resin, aggregates, pigments, binders and glass beads which have been factory produced as a finished product supplied in a preformed state.
- (b) Glass beads shall be uniformly distributed throughout the entire cross sectional area. Immediate retroreflectivity can be provided by a preapplied layer of beads or by scattering surface beads on a molten material during application. The bead adhesion shall be such that beads are not easily removed when the material surface is scratched with a thumbnail.
- (c) The pavement markings shall contain a minimum of 30 percent graded glass beads by weight. The beads shall be clear and transparent and free of pits and scratches. Not more than 20 percent shall consist of irregular, fused spheroids, or silica. The index of refraction shall be not less than 1.50 when tested using the liquid immersion method.
- (d) The pavement markings shall have a minimum thickness of 3.15 mm (125 mils) as supplied by the manufacturer.
- (e) The pavement markings shall be capable of conforming to pavement contours, breaks, and faults through the action of traffic at normal pavement

- temperatures. The markings shall have resealing characteristics and shall be capable of fusing with itself and previously applied thermoplastic when heated with a propane blowtorch.
- (f) The pavement markings shall be resistant to deterioration due to the exposure to sunlight, water, oil, gasoline, salt or adverse weather conditions.
  - (g) The preformed thermoplastic markings shall not be brittle and must be sufficiently cohesive and flexible at temperatures exceeding 10° C (50° F) for one person to carry without the danger of fracturing the material prior to application.
  - (h) The surface of the preformed thermoplastic markings shall provide a minimum skid resistance value of 45 BPN when tested according to ASTM E303-74.
  - (i) The preformed thermoplastic marking material shall have flexibility at 85 degrees such that when a 63 mm x 150 mm (2 1/2 in. x 6 in.) sample is bent through an arc at 90 degrees at a uniform rate in ten seconds (9 degrees/second) over a 25 mm (1 in.) mandrel, no cracking occurs in the test sample. The sample must be conditioned prior to testing at 29 ± 1 °C (85 ± 2 °F) for a minimum of four hours. At least two specimens tested must meet the flexibility requirements at 29 °C (85 °F) for a passing result.
  - (j) Identification. The material shipped to the job site shall be identified by the same shipment number(s), if applicable, batch or lot number(s), as the sample(s) tested and approved for that job. The batch or lot number(s) of the material, and the month and year the material is packaged, shall be stenciled or embossed on the container or included on the label.
  - (k) Sampling and testing. All material samples for acceptance tests will be taken or witnessed by a representative of the Bureau of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766. Random check samples may be taken at the job site at the discretion of the Engineer.

The Engineer will test and certify the basic requirements.

The contractor shall provide the Engineer certification from the manufacturer that the material to be furnished meets all the requirements of these specifications.

Sample(s) of preformed plastic shall be a minimum 0.18 sq m (2 sq ft) of each color to be used.

The sample(s) shall be labeled with the shipment number(s), if applicable, batch or lot number(s), all batch number(s) comprising a lot, date, quantity and any other pertinent information. The sample(s) shall be labeled with the shipment numbers if applicable, batch or lot number(s) comprising a lot, date, quantity and any other pertinent information.

**1095.06 Pavement Marking Tape.** White or yellow marking tape shall consist of glass spheres of high optical quality embedded into a binder on a suitable backing that is precoated with a pressure sensitive adhesive. The spheres shall be of uniform gradation and distributed evenly over the surface of the tape.

The material shall be white or yellow as specified. The colors shall conform closely to Federal color tolerances for pavement marking paint.

The white and yellow tape shall be readily visible when viewed under automotive headlights at night. Reflective values, measured in accordance with the photometric testing procedure of ASTM D4061 shall not be less than those listed in the table below. The Coefficient of Retroreflected Luminance  $R_1$ , shall be expressed as average millicandelas/lux/sq m (millicandelas/foot candle/sq ft), measured on a 600 mm x 300 mm (2 ft x 1 ft) panel at 86 degree entrance angle.

Coefficient of Retroreflected Luminance					
Types I and II			Type III		
Observation Angle	White	Yellow	Observation Angle	White	Yellow
0.2	2700	2400	0.2	1300	1200
0.5	2250	2000	0.5	1100	1000

The pavement marking tape shall have a precoated pressure sensitive adhesive and shall require no activation procedures. Test pieces of the tape shall be applied according to the manufacturer's instructions and tested according to ASTM D 1000, Method A, except that a stiff, short bristle roller brush and heavy hand pressure will be substituted for the weighted rubber roller in applying the test pieces to the metal test panel. Material tested as directed above shall show a minimum adhesion value of 30 g/mm (750 g/in.) width at the temperatures specified in ASTM D 1000. The adhesive shall be resistant to oils, acids, solvents, and water, and shall not leave objectionable stains or residue after removal. The material shall be flexible and conformable to the texture of the pavement.

Type III tape shall be capable of performing for the duration of a normal construction season and shall then be capable of being removed intact or in large sections at pavement temperatures above 4 °C (40 °F) either manually or with a roll-up device without the use of sandblasting, solvents, or grinding. The Contractor shall provide the Engineer certification, from the manufacturer of the Type III tape, that the material to be furnished meets the requirements for being removed after the following minimum traffic exposure based on transverse test decks with rolling traffic:

- (a) Time in place - 400 days
- (b) ADT per lane - 9,000 (28 percent trucks)
- (c) Axle hits - 10,000,000 minimum

Samples of the material, applied to standard specimen plates will be measured for thickness, and tested for durability in accordance with Federal Test Method Standard No. 141A, Method 6192, using a CS-17 wheel and 1000-gram load, and shall meet the following criteria for minimum initial thickness and for durability, showing no significant change in color after being tested for the number of cycles indicated:

Test	Types I & II		Type III	
Initial Thickness mm (Mils)	White 0.51 (20)	Yellow 0.51 (20)	White 0.51 (20)	Yellow 0.51 (20)
Durability (Cycles)	5,000	5,000	1,500	1,500

The pavement marking tape, when applied according to the manufacturer's recommended procedures, shall be weather resistant and shall show no appreciable fading, lifting, or shrinkage during the useful life of the marking. The tape, as applied, shall be of good appearance, free of cracks, and edges shall be true, straight, and unbroken.

**1095.07 Glass Beads for Pavement Markings.** The glass beads used for reflectorizing pavement marking lines shall be Type A or Type B. Type A (uncoated) is intended for use as drop-on beads with solvent-based pavement marking paints and as intermix beads with thermoplastic pavement marking materials. Type B (moisture resistant, silicone coated) is intended for use as drop-on beads with thermoplastic pavement marking materials and waterborne-type marking paints.

- (a) Properties. The glass beads furnished under this specification shall consist essentially of transparent, water-white glass particles of a spherical shape. They shall be manufactured from a glass of a composition designed to be highly resistant to traffic wear and to the effects of weathering. The glass beads shall conform to the following requirements:
  - (1) Sieve Analysis. The glass beads shall meet the following sieve requirements:

Sieve Sizes	U. S. Standard Sieve No.	Total Percent By Mass (Weight) Passing
850 µm	20	100
600 µm	30	75 – 100
300 µm	50	15 – 40
150 µm	100	0 – 5
75 µm	200	0 – 1



- (2) Imperfections. The surface of the glass beads shall be free of pits and scratches. The glass beads shall be spherical in shape and shall contain not more than 20 percent by weight of irregular shapes when tested by the standard method using a vibratile inclined glass plate as adopted by the Department of Transportation.
- (3) Index of Refraction. The index of refraction of the glass beads shall not be less than 1.50 when tested by the immersion method at 25 °C (77 °F).
- (4) Silica Content. The glass beads shall contain not less than 70 percent silica ( $\text{SiO}_2$ ).
- (5) Chemical Stability. Glass beads which show tendency toward decomposition, including surface etching, when exposed to paint or thermoplastic constituents shall be rejected. The glass beads shall be tested according to Federal Specification TT-B-1325B, Section 4.3.9 (water resistance) and evaluated for compliance with Section 3.2.9, with the following exceptions:

The size of sample to be tested shall be 25 grams and the reflux time shall be five hours.

- (6) Flowing Properties. The glass beads shall flow uniformly through dispensing equipment in atmospheric humidity up to 94 percent.
  - a. Type A. The beads shall be free of silicones, waxes, oils, or other coatings and pass the following test:

One hundred grams of glass beads, spread evenly and thinly in a suitable container, shall be conditioned at 25 °C (77 °F) for four hours over a solution of sulfuric acid (Sp. Gr. 1.10) in a closed desiccator. After four hours, the glass beads shall flow readily through a clean glass analytical funnel, 60 degree, 75 mm (3 in.) diameter and 150 mm (6 in.) stem. Inside diameter of the stem shall be a nominal 6.33 mm (1/4 in.).

- b. Type B. The beads shall have a silicone, moisture resistant coating and pass the following test:

One hundred grams of beads are placed in a 600 ml beaker and an equivalent volume of distilled water shall be added to the beaker. The beaker will then stand for five minutes, at the end of which time the water shall be carefully poured off and the beads transferred to a clean dry beaker and allowed to stand for five minutes. The beads will then be poured slowly into a standard glass funnel (Corning 6120), 127 mm (5 in.) diameter, 102 mm (4 in.) stem length and 11 mm (7/16 in.) stem inside diameter. The beads shall flow through the funnel stem without stoppage. Slight initial agitation to start the flow through the funnel at the beginning of the test is permissible.

- (b) Packaging. The glass beads shall be packaged in approved moisture proof bags consisting of at least five ply paper construction unless otherwise specified. Each bag shall contain 22.7 kilograms (50 lb) net, and shall be legibly marked with the manufacturer, IDOT specification and type, lot number, and the month and year the glass beads were packaged. The letters and numbers used in the stencils shall be a minimum of 12.7 mm (1/2 in.) in height.
- (c) Sampling and Testing. Unless otherwise provided, all materials shall be sampled and tested in accordance with the latest published standard methods of the American Society for Testing and Materials, and revisions thereof, in effect on the date of the invitation for bids, where such standard methods exist. In case there are no ASTM Standards which apply, applicable standard methods of the American Association of State Highway and Transportation Officials, or the Federal Government, or of other recognized standardizing agencies shall be used.

The right is reserved to inspect the glass beads either at the place of manufacture or at the destination or at both places. If inspected at the place of manufacture, the manufacturer shall furnish such facilities as may be required for collecting and forwarding samples, and shall also furnish facilities for testing the glass beads during the process of manufacture, if required. During the manufacturing operations, the Department's representative shall have free entry at all times to such parts of the plant as concern the manufacture of the glass beads. Tests will be made by and at the expense of the Department unless otherwise specified.

All material samples for acceptance tests shall be taken or witnessed by a representative of the Bureau of Materials and Physical Research and shall be submitted to the Engineer of Materials and Physical Research, 126 East Ash Street, Springfield, Illinois 62704-4766.

## SECTION 1096. PAVEMENT MARKERS

**1096.01 Raised Reflective Pavement Markers.** Raised Reflective Pavement Markers shall meet the following specifications:

- (a) The markers shall be low profile units consisting of an iron casting conforming to ASTM-A536-84, Grade 72-45-05 hardened to 52-54RC to which is attached a replaceable prismatic retroreflector for reflecting light from one or two directions as specified. The casting shall be shaped to deflect a snowplow blade upward, thus preventing damage to the reflectors. The bottom of the casting shall incorporate two parallel keels and a bow shaped web designed to fit into a grooved road surface. The casting shall have leveling tabs to ensure proper embedment and shall be fastened to the road surface using an epoxy adhesive. The casting shall be designed for bidirectional plowing. The casting shall be marked with the manufacturer's name and the model number of the marker shall be visible after installation.

- (b) The overall dimensions shall be approximately 254 mm (10 in.) long x 140 mm (5.5 in.) wide and a maximum of 45 mm (1.76 in.) high. The installed height shall be approximately 6 mm (0.3 in.) above the road surface. The surface of the keel and web shall be free of scale, dirt, rust, oil, grease, or any other contaminant which may reduce bond.
- (c) The reflector shall be of the prismatic type consisting of a methyl methacrylate or suitably compounded acrylonitrile butadiene styrene (ABS) shell filled with a mixture of an inert thermosetting compound and filler material. The exterior surface of the shell shall be smooth and contain one (monodirectional) or two (bidirectional) methyl methacrylate prismatic reflector faces of the colors specified. The shell shall be fabricated in a manner that will provide a mechanical interlock between the thermosetting compound and the shell. The thermosetting compound shall bond directly to the backside of the metalized lens surface. The manufacturer's trademark shall be molded in the face of the reflector lens or on the reflector body so as to be visible after installation.
- (d) The reflector lens shall be high-intensive type corner cube prismatic and shall provide total internal reflection of the light entering the lens face. The reflector shall be 100 mm (4 in.) long x 50 mm (2 in.) wide x 11 mm (0.44 in.) high and fit securely into a recessed area on the upper surface of the marker casting web. The reflective surface shall be a minimum of 1,030 sq mm (1.6 sq in.) in area. The reflector shall have an abrasion resistant reflective surface.
- (e) The specific intensity of the reflective surface at 0.2 degrees divergence angle shall be as follows when the incident light is parallel to the base of the marker:

Minimum Specific Intensity  
(candelas/lux (candelas/foot candle))

<u>Color</u>	<u>Incidence Angle</u>	
	<u>0°</u>	<u>20°</u>
Crystal	0.28 (3.0)	0.11 (1.2)
Amber	0.16 (1.8)	0.07 (0.7)

The marker color(s) shall be as specified in the plans.

**1096.02 Temporary Raised Reflective Pavement Markers.** Temporary Raised Reflective Pavement Markers shall meet the following specifications:

- (a) The marker shall be of the prismatic type consisting of a methyl methacrylate or acrylonitrile butadiene styrene (ABS) shell. The exterior surface of the marker shall be smooth and contain one (monodirectional) or two (bidirectional) methyl methacrylate cube corner prismatic reflector faces of the color specified. The cube corner prismatic reflectors shall either be molded within the marker or sonically sealed to the face of the shell. The

manufacturer's trademark shall be molded either in the face of the reflector lens or on the shell so it is visible after installation.

- (b) The marker shall have a maximum height of 19 mm (3/4 in.), either rectangular or octagonal in shape and a minimum 100 mm x 75 mm (4 in. x 3 in.) overall. The base of the marker shall be flat. The reflector face shall slope from the base toward the top of the marker. The reflective area of each face shall be a minimum of 225 sq mm (0.35 sq in.) and may be divided into no more than three separate segments.
- (c) The markers, without an adhesive pad, shall support a load of 450 kg (1,000 pounds). This shall be determined by centering a marker over the open end of a vertically-positioned hollow metal cylinder. The cylinder shall be 25 mm (1 in.) in height and have an internal diameter of 75mm (3 in.) and a wall thickness of 6.3 mm (0.25 in.). The load shall be applied slowly to the top of the marker through a 25 mm (1 in.) diameter x 25 mm (1 in.) high metal rod centered on top of the marker. Breakage or significant deformation of the marker shall constitute failure.
- (d) The marker shall have a finish and color that will not fade in ultraviolet conditions or be conducive to tire tracking and will provide good daytime delineation. The specific intensity of the reflective surface at 0.2 degrees divergence angle shall be as follows when the incident light is parallel to the base of the marker.

Minimum Specific Intensity (candelas/lux (candelas/foot candle))		
Color	Incidence Angle	
	0°	20°
Crystal	0.09 (1.0)	0.04 (0.4)
Amber	0.06 (0.6)	0.02 (0.2)

The marker color(s) shall be as specified in the plans.

SECTION 1097. REFLECTORS

**1097.01 General.** The reflectors shall be molded of acrylic plastic into a rectangular or trapezoidal shape designed to transmit a light pattern back toward the light source.

Reflectors shall be constructed of methyl methacrylate (acrylic) plastic and shall have a smooth face free of cracks and checks. The reflectors shall be the color specified in the plans and shall be ready for mounting. The manufacturer's trademark shall be molded in the face of the reflector lens or on the reflector body so it is visible after installation.

**1097.02 Prismatic Barrier Reflectors.** The unit shall have a minimum of 5800 sq mm (9.0 sq in.) of effective reflective area.

Reflectors shall conform to the following minimum specific intensities using the average values of three reflectors for each color:

<u>Color</u>	Minimum Specific Intensity (candelas/lux (candelas/foot candle))		
	Incidence Angle		
	<u>0°</u>	<u>20°</u>	<u>35°</u>
Crystal	5.6 (60)	5.1 (55)	0.8 (9)
Amber	3.3 (36)	3.1 (33)	0.5 (5)

**1097.03 Reflectors for Delineators.** The Contractor shall furnish, when requested to do so, a certification from the manufacturer stating that all reflectors conform to these requirements. The reflectors shall be furnished in either amber or crystal as specified and shall be ready for mounting. The plastic reflector units shall be free of cracks and checks, and fabrication shall be accomplished in a uniform and professional manner.

The reflectors shall be molded of methylmethacrylate plastic and have a clear, smooth and transparent lens (face) with a central mounting hole. The lens shall have a reflective area of not less than 4150 sq mm (6.5 sq in.) nor more than 7750 sq mm (12.0 sq in.) and shall be circular in shape. The manufacturer's trademark shall be molded in the face of the lens.

The rear surface of the lens shall provide reflectivity by a prismatic configuration such that it will affect total retrodirective internal reflection of light incident to the lens surface without the necessity of any plating or separate reflector.

The rear reflective surface of the lens shall be protected by a plastic coated metallic foil back or a separate plastic back fused to the lens under heat and pressure around the entire perimeter and the central mounting hole to form a unit permanently sealed against dust, water, and water vapor.

- (a) Intensity. The coefficient of luminous intensity of each reflector shall be equal to or exceed the following minimum values regardless of reflector orientation.

Divergence Angle Degrees	Entrance Angle Degrees	Intensity Candelas/Lux (Candle Power per Foot Candle)	
		Crystal	Amber
0.1° 0.1°	0°	11.0 (119)	6.6 (71)
	20°	4.4 (47)	2.6 (28)

- (b) Sealing. Submerge five reflectors in a water bath at room temperature. Subject the submerged samples to a vacuum of 125 mm (5 in.) gage for five

minutes. Restore atmospheric pressure and leave the samples submerged for five minutes. The samples shall show no evidence of water intake.

- (c) Heat Resistance. Place three reflectors in a circulating air oven for four hours at  $80\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  ( $175\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$ ). The reflectors shall be placed in a horizontal position on a grid or perforated shelf permitting free air circulation. At the conclusion of the test, the samples shall be removed from the oven and permitted to cool in air to room temperature. The samples shall show no significant change in shape and general appearance when compared with unexposed control standards.
- (d) Housings. One of the following types of housings shall be used:
  - (1) Type A. The back side of the reflector shall be protected by a plastic back fused to the lens under heat and pressure around the entire perimeter and the center mounting hole. The center mounting hole shall have an inside diameter of 5 mm (3/16 in.).
  - (2) Type B. The back side of the reflector shall be protected by a plastic coated metallic foil back, and be housed in 0.5 mm (0.020 in.) aluminum, formed to retain the reflector. The housing shall be provided with four embossed circular reinforcement ribs. An aluminum grommet with a 5 mm (3/16 in.) inside diameter shall be expanded within the reflector mounting hole.